There is disclosed a rotary-pad gas lift plunger. In an embodiment, the pads rotate around the mandrel. This rotation movement results from two features. The first one is the assembly of the mandrel and the pad retaining rings. The second one is the shape of the wearing pad. The rotation movement results from the plunger travel up and down within the tubing. Rotation with uniform wearing helps to maintain the sealing effect between the wearing pads and the inside of the tubing. This uniform wearing on the surface of pads improves efficiency to displace oil and water from oil and gas wells. The uniform wearing also causes a significant increase in the service life of the plunger. Because of the rotation movement, this gas lift plunger can operate in deviated wells where a typical gas lift plunger is restricted.
FIG. 7
US 2016/0237795 A1
Aug. 18, 2016

PLUNGER FOR LIFTING FLUIDS WITHIN A TUBING STRING

BACKGROUND

[0001] Within the oil and gas industry, a plunger is an artificial lift device used to increase hydrocarbon production on wells whose gas flow is reduced by a weight of accumulated fluids sitting on top of the gas flow. By closing and opening the sales valve, and by other means, a plunger is made to travel toward the bottom of the tubing string and then ascend under internal gas pressure, carrying a slug of liquid above it that will be removed from the well, thereby increasing production. Inefficiency in a plunger system is related to the amount of fluid that slips past its seal during ascent (fluid slippage). A wide range of designs is necessary to accommodate a wide range of well conditions such as production rate, gas pressure, gas-to-liquid ratio, profit margin, irregularities in tubing diameter, doglegs, debris, contaminants, and corrosives. Unfortunately, since the plunger is a tight-lifting device, wear is a significant issue, including one-sided wear, eventually necessitating a replacement or repair cost.

[0002] One solution to keeping costs low may be to use a bar stock plunger having few or no moving parts, the surface being arrayed with flutes or grooves stacked axially to generate a sealing turbulence. However, significant fluid slippage may occur in this simple design, especially at low travel speeds. And, only one degree of freedom exists in responding to changing tubing conditions, which is to adjust the speed of the plunger through the plunger control system.

[0003] Alternatively, a higher efficiency may be obtained by use of a pad plunger in which an array of circular pads are deployed around the mandrel and spring biased against the inner surface of the tubing string, allowing individual pads to move radially in an out, and to toggle circumferentially. Thereby, two degrees of freedom exist, an improvement allowing a greater responsiveness to changes in tubing diameter, angular bends in the string, and debris, and may result in greater efficiency. But, one-sided wear may occur, especially in a non-vertical string and when encountering debris. Wearing stripes may also occur in a straight well where one side of the plunger abrades against the tubing string, causing a deterioration of sealing performance and requiring premature repair or replacement.

[0004] A solution to one-sided wear is to induce pad rotation by arraying spirals or grooves onto the wear surfaces of the sealing pads. However, the grooves depend on a strong fluid flow to generate rotation and do not work as well at low travel speeds. Also, the grooves, which often double as wear indicators in the range of approximately 0.015-0.030", eventually wear flat so that they are no longer effective. Additionally, the rotational inertia of the plunger may be high, corresponding to high weight of the plunger (typically 6 to 18 pounds), and therefore the mandrel cannot rotatably respond quickly to a change in tubing conditions, leading to wear and fluid slippage.

[0005] Another solution, aiming to improve the seal, uses multiple sets of pads, such as a dual-pad plunger with articulating pads, that can better corner doglegs in the tubing and also responds with two degrees of freedom (toggling radially and circumferentially) to changing string conditions. However, the complexity of the dual-pad plunger makes it heavy, thereby causing a greater potential for damage to the tubing string that it's abrading against.

SUMMARY

[0006] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key aspects or essential aspects of the claimed subject matter. Moreover, this Summary is not intended for use as an aid in determining the scope of the claimed subject matter.

[0007] In an embodiment, there is provided a plunger for lifting fluids within the tubing string of a hydrocarbon well and which may comprise an elongated mandrel having a mandrel axis and a circumferential surface. At least 2 arcuate pads may be disposed circumferentially around the mandrel, and may form a pad set. The arcuate pads may each have a pad upper end and a pad lower end. Each arcuate pad may have a wear surface cooperating to form a substantially contiguous cylindrical seal against an inner surface of the tubing string. At least one spring may be disposed between the mandrel and the arcuate pad for biasing the arcuate pad outwardly radially such that the wear surfaces are moveably in contact with the inner surface of the tubing string. At least one circular guide may be disposed on the mandrel and may each engage a complementary receptacle of the arcuate pad for substantially restricting the motion of the arcuate pad to be circumferential around the mandrel axis. An annular retainer may be disposed around the mandrel for enclosing one of the pad upper end, the pad lower end, the pad upper end of one pad set and the pad lower end of another pad set. The annular retainer may limit outward radial movement of the arcuate pad. The at least one circular guide, complementary receptacles, springs, and annular retainers may cooperate to allow rotation of the arcuate pads about the mandrel axis while radially biasing the arcuate pads against the inner surface of the tubing string, thereby lifting fluids within the tubing string.

[0008] In another embodiment, there is provided a plunger for lifting fluids within the tubing string of a hydrocarbon well and which may comprise an elongated mandrel having a mandrel axis and a circumferential surface. At least 2 arcuate pads may be disposed circumferentially around the mandrel to form a pad set. Each arcuate pad may have a pad upper end and a pad lower end. Each arcuate pad may have a wear surface arcing between two pad side edges and which may cooperate to form a substantially contiguous cylindrical seal against an inner surface of the tubing string. At least one spring may be disposed between the mandrel and the arcuate pad for biasing the arcuate pad outwardly radially such that the wear surfaces are moveably in contact with the inner surface of the tubing string. An annular retainer may be disposed around the mandrel and may enclose either the pad upper end, the pad lower end, or the pad upper end of a first pad set and the pad lower end of a second pad set. The annular retainer may limit outward radial movement of the arcuate pad. A pad gap may separate the pad side edges of two adjacent arcuate pads and may provide a channel for fluids to flow between the pad upper end and the pad lower end. The arcuate pad may be shaped as a rhombus for slanting the pad gap oblique to the mandrel axis by a pad slant angle of less than approximately 35 degrees for encouraging rotation of the arcuate pads.

[0009] Additional objects, advantages and novel features of the technology will be set forth in part in the description which follows, and in part will become more apparent to those skilled in the art upon examination of the following, or may be learned from practice of the technology.
BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Non-limiting and non-exhaustive embodiments of the present invention, including the preferred embodiment, are described with reference to the following figures, wherein like reference numerals refer to like parts throughout the various views unless otherwise specified. Illustrative embodiments of the invention are illustrated in the drawings, in which:

[0011] FIG. 1 illustrates a side sectional view of a dual-pad plunger having a circular guide, in accordance with an embodiment of the present disclosure.

[0012] FIG. 2 illustrates a side view of a dual-pad plunger having a circular guide, in accordance with an embodiment of the present disclosure.

[0013] FIG. 3 illustrates a close-up side sectional of a collar lip enclosing a pad end, in accordance with an embodiment of the present disclosure.

[0014] FIG. 4 illustrates an axial sectional view of a guide rail and guide slot, in accordance with an embodiment of the present disclosure.

[0015] FIG. 5 illustrates an axial sectional view of edge spacers with pads biased outward, in accordance with an embodiment of the present disclosure.

[0016] FIG. 6 illustrates an axial sectional view of edge spacers with pads in a deflected position, in accordance with an embodiment of the present disclosure.

[0017] FIG. 7 illustrates an axial sectional view of a spring bearing supporting biasing springs, in accordance with an embodiment of the present disclosure.

[0018] FIG. 8 illustrates a side view of a plunger having edge spacers, in accordance with an embodiment of the present disclosure.

[0019] FIG. 9 illustrates a perspective view of a dual-pad plunger having a slanted pad gap, in accordance with an embodiment of the present disclosure.

[0020] FIG. 10 illustrates a side sectional view of a dual-pad plunger with a slanted pad gap, in accordance with an embodiment of the present disclosure.

[0021] FIG. 11 illustrates a side sectional view of a dual-pad plunger having a guide wheel, in accordance with an embodiment of the present disclosure.

[0022] FIG. 12 illustrates an axial sectional view of a plunger having a guide wheel, in accordance with an embodiment of the present disclosure.

[0023] FIG. 13 illustrates a side sectional view of a shortened plunger having one set of double pads, in accordance with an embodiment of the present disclosure.

[0024] FIG. 14 illustrates a side view of a shortened plunger having one set of double pads, in accordance with an embodiment of the present disclosure.

[0025] FIG. 14a illustrates a side-sectional view of a bypass plunger having a circular guide, in accordance with an embodiment of the present disclosure.

[0026] FIG. 14b illustrates a side view of a bypass plunger having a circular guide, in accordance with an embodiment of the present disclosure.

[0027] FIG. 15a illustrates an axial sectional view of a standoff ring for a plunger, in accordance with an embodiment of the present disclosure.

[0028] FIG. 15b illustrates a side sectional close-up view of a standoff for a plunger, in accordance with an embodiment of the present disclosure.

[0029] FIG. 16 illustrates a perspective view of a plunger having two pad sets rotatable on finger rings and clocked at an angular offset, in accordance with an embodiment of the present disclosure.

[0030] FIG. 17 illustrates a side view of a plunger having rhombus-shaped pads rotatable on finger rings and pad sets clocked at an angular offset, in accordance with an embodiment of the present disclosure.

[0031] FIG. 18a illustrates a side sectional view of a dual-pad plunger having pad sets rotatable on finger rings and clocked at an angular offset, in accordance with an embodiment of the present disclosure.

[0032] FIG. 18b illustrates a side sectional view of a finger ring mating with a clocking ring and enclosed by a central collar, in accordance with an embodiment of the present disclosure.

[0033] FIG. 19a illustrates a perspective view of a clocking ring with axial fingers for retaining the pads, in accordance with an embodiment of the present disclosure.

[0034] FIG. 19b illustrates a side sectional view of a clocking ring with axial fingers, in accordance with an embodiment of the present disclosure.

[0035] FIG. 20a illustrates a perspective view of a finger ring with axial fingers for retaining the pads, in accordance with an embodiment of the present disclosure.

[0036] FIG. 20b illustrates a side sectional view of a finger ring with axial fingers, in accordance with an embodiment of the present disclosure.

[0037] FIG. 21a illustrates a perspective view of a central collar for retaining the pads, in accordance with an embodiment of the present disclosure.

[0038] FIG. 21b illustrates a side sectional view of a central collar for retaining the pads, in accordance with an embodiment of the present disclosure.

[0039] FIG. 22a illustrates a perspective view of an end collar for retaining the pads, in accordance with an embodiment of the present disclosure.

[0040] FIG. 22b illustrates a side sectional view of an end collar for retaining the pads, in accordance with an embodiment of the present disclosure.

[0041] FIG. 23 illustrates an exploded view of a plunger having two pad sets rotatable on finger rings and clocked at an angular offset, in accordance with an embodiment of the present disclosure.

[0042] FIG. 24a illustrates a perspective view of a mandrel with threads at each end, in accordance with an embodiment of the present disclosure.

[0043] FIG. 24b illustrates a side sectional view of a mandrel with threads at each end, in accordance with an embodiment of the present disclosure.

[0044] FIG. 25a illustrates a perspective view of an arcuate pad having a rhombus shape.

[0045] FIG. 25b illustrates a perspective view of the arcuate pad of FIG. 25a in which there is a view of a pair of spring cavities.

[0046] FIG. 25c illustrates a bottom view of the arcuate pad of FIGS. 25a and 25b in which there is a view of the pair of spring cavities.

DETAILED DESCRIPTION

[0047] Embodiments are described more fully below in sufficient detail to enable those skilled in the art to practice the system and method. However, embodiments may be implemented in many different forms and should not be construed
as being limited to the embodiments set forth herein. The following detailed description is, therefore, not to be taken in a limiting sense.

[0048] As may be appreciated, based on the disclosure, there exists a need in the art for a lift plunger with more even wear around the sealing surface, and reduced wear in general. Further, there exists a need in the art for a plunger with improved lift efficiency, especially at slow speeds. Additionally, there exists a need in the art for a greater degree of freedom in the movement of the wear surfaces in order to better respond to dimensional irregularities and debris in the tubing string. Also, there exists a need in the art for the plunger seal to respond more quickly to changing conditions. And finally, there exists a need in the art for a plunger system that poses a lower risk of damage to the tubing string.

[0049] In an embodiment, referring to FIGS. 1-4 and FIG. 6, a lift plunger 10 may comprise two pad sets 11 of arcuate pads 12 stacked axially in a dual pad plunger arrangement for use in lifting fluids to the surface in a hydrocarbon well, such as a well for oil and gas. Each pad set 11 of arcuate pads 12 may be disposed circumferentially around the mandrel 30 such that wear surfaces 20 cooperate to form a substantially contiguous cylindrical seal against the inner surface of the tubing string 16 (FIG. 6). A top end 34 (also known as a catching neck) may terminate mandrel 30 and may provide an annular lip 56 for enclosing and retaining a pad upper end 24 for limiting outward radial movement of the arcuate pad 12. A bottom end 32 may terminate mandrel 30 and may provide an annular lip 56 for enclosing and retaining a pad lower end 24 for limiting outward radial movement of the arcuate pad 12. Bottom end cavity 38 may be formed in bottom end 32 in order to provide greater gas lift. A collar 50 may wrap around circumferential surface 36 of mandrel 30 to provide a collar lip 52 on both ends for enclosing pad upper end 24 and pad lower end 22, thereby limiting outward radial movement of arcuate pad 12. Alternatively, an annular lip 56 may be disposed directly on the circumferential surface 36 of mandrel 30 (FIG. 3).

[0050] Referring to FIGS. 1 and 6, in an embodiment, springs 60 may be disposed between spring bearing 64 and a spring cavity 62 recessed into the underside of arcuate pad 12 for bising arcuate pads 12 outwardly axially. As shown in this embodiment, there may be two springs 60 for each of four arcuate pads per spring bearing, and two spring bearings per arcuate pad, for a total of sixteen springs per pad set 11. Spring bearing 64 may slide circumferentially on spring bearing shaft 66 joining an upper and lower portion of mandrel 30. Spring bearing shaft 66 may be formed as a recess in mandrel 30, or may be a specialized bearing joining an upper and lower portion of mandrel 30. Spring bearing 64 axially located by the recess in mandrel 30 may comprise a circular guide for substantially restricting motion to be circumferential about mandrel axis 36 (not shown). Springs 60 and spring cavity 62 may comprise a complementary receptacle in arcuate pad 12 for enabling rotation. Arcuate pads 12 may be advantageously biased by springs 60 into contact with inner surface of the tubing string 16 in order to adapt to changes in tubing diameter or respond to the presence of debris, thereby maintaining a seal that avoids fluid slippage during ascent of plunger 10. Since most of the pressure directed by the sealing action may be directed through biasing springs 60, and not onto other components disposed on the mandrel 30, a bearing surface may be most needed at the interface between spring 60 and mandrel 30.

[0051] Continuing, in an embodiment, FIGS. 1 and 4 show, respectively, a side sectional and axial sectional view of guide rail 40 disposed on mandrel 30 and complementary guide slot 42 disposed on the underside of arcuate pad 12 and which may together form a circular guide and complementary receptacle for guiding arcuate pads 20 in rotation around the mandrel’s elongated axis (not shown). The sides of guide rail 40 and guide slot 42 may fit closely to minimize axial movement of arcuate pads 12. A rail radial gap 41 between guide rail 40 and guide slot 42 may allow the arcuate pads 12 to flex radially between bottoming ledge 54 and the enclosing limits provided by annular lips 56 and collar lips 52, thereby responding to diameter or pressure changes within the tubing string 14 (FIG. 6). The function of bottoming ledge 54 may also be obtained from guide rail 40 by allowing rail radial gap 41 to close. Alternatively, a hooked surface (not shown) may be added to the circular guide to radially limit the arcuate pads 12 to a maximum outward movement and thereby may reduce the need for an annular lip 56 or collar lip 52.

[0052] Continuing with FIGS. 1-4 and FIG. 6, in an embodiment, pad side edges 26 of adjacent arcuate pads 12 may bracket pad gap 90, creating a channel through which fluids may flow around lift plunger 10. Pad gap 90 may also be filled with a gasket or seal to reduce fluid slippage and improve lift efficiency. In an embodiment, a set of four springs per arcuate pad that are positioned off center may provide a toggling degree of freedom in both an axial plane and a circumferential plane. The top of guide rail 40 and mating surface of guide slot 42 may be rounded (not shown) to allow for axial toggling while still preventing a shift in axial position. Alternatively, a small gap in the mating sides of guide rail 40 and guide slot 42 may also allow for axial toggling of arcuate pad 20 while sufficiently limiting axial positioning.

[0053] Continuing, in an embodiment, by providing a circular guide and complementary receptacle for pad rotation, an additional degree of freedom (swiveling or rotating) may prevent undue or one-sided wear due to dimensional irregularities and debris in the tubing string. For example, a slant well (not shown) may have a non-vertical tubing string (14) which causes the plunger to lie on one side, leading to one-sided wear. And, sharp bends in the slant well may compress one or more pads and cause undue wear in a stationary or fixed-pad plunger. However, a lift plunger 10 with rotatable pads, such as the design disclosed herein, may deflect one or more arcuate pads rotationally in response to a dimensional change, or in response to a deposit of paraffin, thereby spreading wear more evenly among all arcuate pads and increasing lift efficiency, even at slow travel speeds. Additionally, unlike a fixed-pad plunger having high rotational inertia, the swivel pads may respond quickly to irregularities in the tubing string 14 because the pads have much lower inertia than the plunger as a whole. The arcuate pads may therefore rotate while the mandrel 30 stays still.

[0054] Referring to FIGS. 2, 15a, and 15b, in an embodiment, an axial standoff 44 may protrude radially into pad cutout 28 in the center-end of arcuate pad 12, stabilizing arcuate pad 12 in its circumferential position and establishing a consistent pad gap 90 between pad side edges 26. In a fixed-pad plunger (without rotation of the pads), axial standoffs 44 may be disposed directly on mandrel 30 for establishing a circumferential and axial position for each arcuate pad while allowing toggling in both planes. In an embodiment, axial standoffs 44 along all pad ends in a pad set 11 may be disposed on a standoff ring 46 rotating as a bearing on cir-
cumferential surface 36 between standoff ledges 49 of mandrel 30, and may comprise a circular guide for substantially restricting motion to be circumferential. Axial standoff 44 and pad cutout 28 may be dimensioned to allow a full play between maximum and minimum radial biasing by springs 60. Collar lip 52 may contact pad upper end 24 at a maximum biasing while bottoming ledge 54 may contact circumferential surface 36 at a minimum biasing (FIG. 10).

[0055] In an alternative embodiment not shown, one long standoff bearing sliding on circumferential surface 36 and extending between standoff ledges 49 may support an array of axial standoffs 44 functioning as a circular guide and mating with pad cutouts 28 functioning as complementary receptacles. Additionally, one or more springs 60 may be disposed between the long standoff bearing and the arcuate pads for biasing the pads outwardly and allowing axial and circumferential toggling.

[0056] FIGS. 5a, 5b and FIG. 7, in an embodiment, may suggest an alternative to using axial standoffs 44, or similar means, for maintaining an even spacing between adjacent arcuate pads 12. Flexible edge spacers 58 may be placed between pad side edges 26 in a way that allows independent deflection of wear surface 20 by debris 94 (FIG. 5b) or other irregularities inside the tubing string 14 while maintaining an even spacing between arcuate pads 12. Edge spacer 58 may have concave ends for receiving pad side edge 26 while allowing pivoting of edge spacer 58 and a toggling articulation of arcuate pads 12. Or, edge spacer 58 may clip onto an indentation or mating axle on the pad side edge 26 (not shown). Additionally, a flexible material such as Teflon may allow deflection while reducing play in the attachment of the edge spacer 58 to pad side edge 26.

[0057] In an embodiment, referring to FIG. 7, arcuate pads 12 having wear surfaces 20 may be disposed on a mandrel 30 (not shown) having top end 34 and bottom end 32. A circular guide design may be combined with edge spacers 58 by including a guide rail 40 and guide slot 42 (not shown here), as mentioned above, or an alternate method of guiding circumferential rotation of arcuate pads 12. Springs 60 may be integrated into an edge spacer with a rail and slot design, or may be provided for separately, such as with a spring bearing. Annular lip 56 may enclose pad upper end 24 and may enclose pad lower end 22 for limiting outward radial movement of arcuate pad 12. Collar lip 52 of collar 50 may enclose pad upper end 24 and may enclose pad lower end 22 for limiting outward radial movement of arcuate pad 12.

[0058] Alternate methods of implementing a circular guide will be shown in subsequent descriptions which may provide for rotation, or swiveling, of arcuate pads 20 about the mandrel axis. Additionally, alternate methods of disposing springs 60 on mandrel 30 may include using an arched or leaf spring sliding directly on circumferential surface 36. Or, spring 60 may slide on circumferential surface 36 using an independent ball bearing element, and may thereby reduce to one the number of bearing rings needed for each pad set 11 in order to accomplish a swivel pad design. For instance, a rail and guide bearing (not shown) may comprise a guidance system with a number of frictionless elements 58, 59 to allow rotation with the ball bearing element, and may thereby reduce, to one the number of bearing rings. In another embodiment, the amount of rotation may be limited to a subset of 360 degrees in order to employ simpler or less expensive manufacture by methods known to those skilled in the art, and yet may still accomplish an improved seal efficiency and reduced wear of the lift plunger 10.

[0059] Referring now to FIGS. 10 and 11, in an embodiment, the circular guide and spring biasing functions may be integrated into one structure which may comprise a guide wheel 80 having a wheel spoke 82 slideably mating with pad shaft 84 disposed on arcuate pad 12. Spring 60 in spring cavity 62 may be interposed between pad shaft 84 and wheel spoke 82 to provide outward radial biasing. A wheel bearing 81 portion of guide wheel 80, from which wheel spokes 82 may extend radially, may rotate on a wheel shaft 86 interposed between and coaxial with a mandrel upper portion 106 and a mandrel middle portion 104, in case of the upper assembly. And, wheel bearing 81 may rotate on a wheel shaft 86 interposed between and coaxial with a mandrel lower portion 102 and a mandrel middle portion 104, in case of the lower assembly. Mandrel upper, middle, and lower portions may comprise mandrel 30.

[0060] Referring to FIGS. 10 and 11, in an alternate embodiment not shown, pad shaft 84 may have at least one flat side mating with a complementary surface of wheel spoke 82 for preventing twisting of arcuate pad 12 out of the circumferential plane of rotation. For example, pad shaft 84 may be rectangular and slideably mate with wheel spoke 82. By shaping wheel spokes 82 to prevent rotation, it may not be necessary to employ axial standoffs 44, edge spacers 58, or guide rail 40 in fabricating a plunger having outwardly radially biased rotatable pads. In another embodiment shown in FIG. 12, a pad set 11 may be guided for circumferential rotation by two guide wheels 80 distributed along the mandrel axis (not shown), thereby preventing the pads from twisting out of their plane of rotation, where the two springs in each pad may enable axial toggling of the pads. In yet another embodiment (not shown), referring to FIGS. 11 and 6, two wheel spokes supporting one pad may extend from a wheel bearing, also preventing the pads from twisting out of their plane of rotation, where the two springs in each pad may enable circumferential toggling of the pads.

[0061] Continuing with FIGS. 10 and 11, in an embodiment, collar lips 52 of collar 50 may enclose pad upper end 24 and pad lower end 22, and annular lips 56 may be disposed on circumferential surface 36 for enclosing and retaining pad upper end 24 and pad lower end 22, both annular and collar lips limiting outward radial movement of the arcuate pads 12 having wear surfaces 20 biased against the inner surface of the tubing string 16. Bottoming ledge 54 may be disposed on the underside of arcuate pad 12 (FIG. 10) and positioned to contact circumferential surface 36 for establishing a minimum radius of outward biasing of arcuate pads 12. Alternatively, bottoming ledge 54 may be disposed on circumferential surface 36 (FIG. 11). Mandrel top end 34 may terminate mandrel upper portion 106 and bottom end 32 having bottom end cavity 58 may terminate mandrel lower portion 102.

[0062] Advantageously, in embodiments described above, including FIGS. 10 and 11, there may be several methods for providing the circular guide and spring biasing functions, or integrating the two functions into one structure, and where the method selected may depend upon the degrees of freedom most effective in minimizing wear and maximizing lift efficiency, upon the amount of irregularity and debris in the tubing string, and cost factors. Several design features may contribute to an improved lift plunger, and may include adding circumferential rotation not dependent on grooves or spirals embossed on the surface of the plunger, reducing rota-
ional inertia by separating pad rotation from the mandrel, providing several means for maintaining correct pad edge spacing, and integrating spring biasing and circular guiding. Additional embodiments will be described which may depict additional methods for achieving the above advantages.

[0063] Now referring to FIGS. 8 and 9, in an embodiment, a dual-pad plunger 10 may comprise two pad sets 11 of four arcuate pads 12 each disposed circumferentially on a mandrel 30 (not shown) terminated with top end 34 and bottom end 32, both ends having beveled sides 37 for reducing the risk of damage to tubing string 14 (not shown). Pad gap 90 between pad side edges 26 may provide a channel for fluids to flow between the pad lower end and the pad upper end, and the channel may be oblique to the mandrel axis 31 by a pad slant angle 92 of less than approximately 35 degrees for encouraging rotation of the arcuate pads. The effect of a slanted pad gap may be to form the arcuate pad to be in the shape of a rhombus, or parallelogram. In an embodiment, a pad slant angle of less than approximately 15 degrees may generate rotation of the arcuate pads. Axial standoff 44 protruding radially into pad cutouts 28 may be disposed directly on mandrel 30 in a fixed pad design (without pad rotation) for fixing pad location both axially and circumferentially. Alternatively, axial standoff 44 may be disposed on a standoff ring or other structure linking multiple axial standoff together for permitting rotation of a pad set 11 with respect to the mandrel. By providing a pad gap 90 oblique to the mandrel axis 31, fluid flow may induce wear surfaces 20 of arcuate pads 12 to rotate with respect to the tubing string either independent of or dependently with the mandrel.

[0064] Continuing with FIGS. 8 and 9, in an embodiment, collar lips 52 of collar 50 may enclose pad upper end 24 and pad lower end 22, and annular lips 56 may be disposed on circumferential surface 36 for enclosing pad upper end 24 and pad lower end 22, both annular and collar lips limiting outward radial movement of the arcuate pads 12. In an embodiment, the upper and lower pad sets 11 may be offset by an angular offset for preventing fluid slippage by creating a less direct path for fluid flow across the pads, or may be offset in order to allow pads to independently adapt to irregularities in the tubing string. For example, in an embodiment having four arcuate pads 12 spanning approximately 90 degrees each, the two pad sets may be offset by an angular offset of approximately 45 degrees. In other embodiments, the two pad sets may be aligned (0 degrees), or may be offset by 30 degrees or 60 degrees. In a dual-pad plunger 10 having rotatable pads, collar 50 may be configured as a clocking collar (not shown) having clocking tabs protruding into the pad gap for fixing the angular offset while the two pad sets rotate together.

[0065] Referring now to FIGS. 12 and 13, in an embodiment, a shortened lift plunger 10 may comprise a mandrel wrapped with one pad set 11 of arcuate double pads 13 having a pad upper end 24 and pad lower end 22 enclosed by annular lips 56 for limiting the maximum outward radial extension of the arcuate double pads 13. Double pad indentation 74 may be by a recess below wear surfaces 20 and may separate the upper and lower portions of arcuate double pad 13. A top end 34 may have a beveled side 37 for streamlining the plunger 10. A plurality of spiral grooves 72 may be disposed on bottom end 32 for inducing rotation in the plunger as a response to fluid flow within tubing string 14 (not shown). Alternatively, spiral grooves 72 may also be disposed on top end 34 for encouraging rotation.

[0066] Continuing with FIGS. 12 and 13, in an embodiment, two guide wheels 80 may support the double pads 13, each guide wheel 80 having a wheel spoke 82 slidable mating with pad shaft 84 disposed on arcuate pad 12. Spring 60 in spring cavity 62 may be interposed between pad shaft 84 and wheel spoke 82 to provide outward radial biasing. A wheel bearing 81 portion of guide wheel 80, from which wheel spokes 82 may extend radially, may rotate on a wheel shaft 86 interposed between and coaxial with a mandrel upper portion 106 and a mandrel middle portion 104, in case of the upper assembly. And, wheel bearing 81 may rotate on a wheel shaft 86 interposed between and coaxial with a mandrel lower portion 102 and a mandrel middle portion 104, in case of the lower assembly. Mandrel upper, middle, and lower portions may comprise mandrel 30. Bottoming ledges 54 may be disposed on the underside of the arcuate double pads 13 for contacting circumferential surface 36, thereby setting a minimum radial extension of pads 13. Advantageously, the shortened plunger may be more maneuverable around bends in the tubing string, and its two guide wheels may prevent the pads 13 from twisting out of their plane of rotation while allowing for an articulating wear surface 20 that can toggle axially or circumferentially.

[0067] Referring now to FIGS. 14a and 14b, in an embodiment, a dual-pad plunger 10 may comprise two pad sets 11 of four arcuate pads 12 each disposed around circumferential surface 36 and positioned toward top end 34 terminating mandrel 30. Bottom end 32 may terminate mandrel 30 and may house bypass actuator 110 sliding to open and close bypass inlet 112 for admitting fluid flow 78 into mandrel hollow 114 for conduction to a bypass outlet 116 in the top end 34. Pad gap 90 between pad side edges 26 may provide a channel for fluids to flow between pad lower end 22 and pad upper end 24, and the channel may be oblique to the mandrel axis 31 by a pad slant angle 92 of less than approximately 35 degrees for encouraging rotation of the arcuate pads. The arcuate pad may have the shape of a rhombus, or parallelogram. Preferably, pad slant angle 92 may be less than approximately 15 degrees.

[0068] Continuing with FIGS. 14a and 14b, in an embodiment, collar lips 52 of collar 50 may enclose pad upper end 24 and pad lower end 22, and annular lips 56 may be disposed on circumferential surface 36 for enclosing pad upper end 24 and pad lower end 22, both annular and collar lips limiting outward radial movement of the arcuate pads 12. In an embodiment, the upper and lower pad sets 11 may be offset by an angular offset for preventing fluid slippage by creating a less direct path for fluid flow across the pads, or may be offset in order to allow pads to independently adapt to irregularities in the tubing string. For example, in an embodiment having four arcuate pads 12 spanning approximately 90 degrees each, the two pad sets may be offset by an angular offset of approximately 45 degrees. In other embodiments, the two pad sets may be aligned (0 degrees), or may be offset by 30 degrees or 60 degrees. In a dual-pad plunger 10 having rotatable pads, collar 50 may be configured as a clocking collar (not shown) having clocking tabs protruding into the pad gap for fixing the angular offset while the two pad sets rotate together.

[0069] Continuing with FIGS. 14a and 14b, in an embodiment, guide rail 40 disposed on mandrel 30 and complementary guide slot 42 disposed on the underside of arcuate pad 12 may together form a circular guide and complementary receptacle for guiding arcuate pads 12 with wear surface 20 in rotation around mandrel axis 31. The sides of guide rail 40 and guide slot 42 may fit closely to minimize axial movement of arcuate pads 12. A rail radial gap 41 between guide rail 40
and guide slot 42 may allow the arcuate pads to flex radially. Springs 60 may be disposed between spring bearing 64 and a spring cavity 62 recessed into the underside of arcuate pad 12 for biasing arcuate pads 12 outwardly radially. As shown in this embodiment, there may be two springs 60 for each of four arcuate pads per spring bearing. Spring bearing 64 may slide circumferentially on spring bearing shaft 66 joining an upper and lower portion of mandrel 30. Spring bearing shaft 66 may be formed as a recess in mandrel 30, or may be a specialized bearing joining an upper and lower portion of mandrel 30.

[0070] Alternately, referring still to FIGS. 14a and 14b, in an embodiment, a bypass feature may be incorporated into a fixed pad plunger having a pad gap 90 oblique to mandrel axis 31 and having axial standoffs to position arcuate pads 12 both axially and circumferentially. In another embodiment, a bypass feature may be incorporated into a plunger having a guide wheel 80 integrating spring biasing with circularly guiding the arcuate pads in rotation. Advantageously, several design features may contribute to an improved lift plunger, and may include adding circumferential rotation not dependent on grooves or spirals embossed on the surface of the plunger, reducing rotational inertia by separating pad rotation from the mandrel, providing several means for maintaining correct pad edge spacing, and integrating spring biasing and circular guiding.

[0071] In an embodiment, referring to FIGS. 16 and 17, a lift plunger 10 in a dual pad plunger arrangement for use in lifting fluids to the surface in a hydrocarbon well, such as a well for oil and gas. Each set of arcuate pads 12 may be disposed circumferentially around the mandrel 30 (FIG. 18) such that wear surfaces 20 cooperate to form a substantially contiguous cylindrical seal against the inner surface of the tubing string 16 (not shown). Pad gap 90 between pad side edges 26 may provide a channel for fluids to flow between the pad lower end and the pad upper end. The channel formed by pad gap 90 may be oblique to the mandrel axis 31 (not shown) by a pad slant angle 92 (not shown) of less than approximately 35 degrees, thereby forming arcuate pad 12 in the shape of a rhombus and encouraging rotation of the arcuate pads. Alternatively, in an embodiment, the channel formed by pad gap 90 may be parallel to the mandrel axis, resulting in a rectangular shape for arcuate pad 12 and not encouraging rotation. For example, referring to FIG. 16, pad gap 90 may be disposed in a slight clockwise slant, going from top to bottom, or referring to FIG. 17, disposed in a counterclockwise slant, both resulting in a rhombus shape and encouraging a rotation of arcuate pads 12.

[0072] Continuing with FIGS. 16 and 17, in an embodiment, top end 34 and a bottom end 32 may cap mandrel 30. Top end 34 may also be known as a catching neck for retrieving the plunger from a well. The distal end of end collars 51 may be adjacent to top end 34 and bottom end 32, and may be shaped as a cylindrical sleeve. The central end of end collars 51 may provide a collar lip 52 for enclosing a pad upper end 24 (not shown) or a pad lower end 22 (not shown) for limiting outward radial movement of the arcuate pad 12. A central collar 53 may be a cylindrical sleeve providing a collar lip 52 on both ends for enclosing pad upper end 24 of one pad set and pad lower end 22 of the adjacent pad set, thereby limiting outward radial movement of arcuate pad 12. Alternatively, an annular lip may be disposed directly on the circumferential surface 36 (not shown) of mandrel 30 (not shown) to enclose pad upper end 24 and pad lower end 22. Bottom end cavity 38 may be formed in bottom end 32 in order to provide greater gas lift.

[0073] Continuing with FIGS. 16 and 17, in an embodiment, finger ring 47 (partially shown) may bear rotatably on circumferential surface 36 near the distal ends of mandrel 30 and may project fingers axially into pad cutout 28 for retaining arcuate pad 12 while allowing radial movement under the outward biasing of one or more springs 60 (not shown) disposed between the underside of arcuate pad 12 and mandrel 30. Finger ring 47 may lie beneath end collar 51 and may be restrained axially outwardly by top end 34 or bottom end 32. Together, finger ring 47 and one of mandrel ends 34 or 32 may provide a circular guide substantially restricting the motion of the arcuate pad to be circumferential around the mandrel axis, thereby enabling a lift plunger 10 with rotatable pads. In an embodiment not shown, there may be only one pad set, and finger rings 47 and end collars 51 may be sufficient to enable rotation of the pad set. Alternately, an element 47 may project into pad cutout 28 and be fixed on mandrel 30 for retaining arcuate pad 28 without providing rotation.

[0074] Continuing with FIGS. 16 and 17, in an embodiment, a plunger comprising multiple pad sets may comprise a central finger ring 47 (partially shown) bearing rotatably on circumferential surface 36 between two adjacent pad sets and may project fingers axially into pad cutout 28 for retaining arcuate pad 12 of one pad set while allowing radial movement. A plunger having multiple pad sets may further comprise a clocking ring 43 (partially shown) mating with the central finger ring 47 such that they rotate together under central collar 53, the clocking ring 43 bearing rotatably on circumferential surface 36 and projecting fingers into the pad cutouts of the adjacent pad set. The two pad sets may be located axially by the sandwiching of finger ring 47 mated adjacently to clocking ring 43. Central finger ring 47 and clocking ring 43 may each, in combination with pad cutout 28, provide a circular guide for arcuate pads 12, thereby substantially restricting the motion of the arcuate pads to be circumferential around the mandrel axis, thereby enabling a lift plunger 10 with rotatable pads. For the dual pad plunger shown in FIGS. 16 and 17, there may be four circular guides comprising three finger rings 47 and one clocking ring 43, each circular guide engaging pad cutouts 28 functioning as complementary receptacles, the circular guides and complementary receptacles retaining two pad sets while allowing rotation of arcuate pads 12 around mandrel 30.

[0075] Continuing, in an embodiment, central finger ring 47 and clocking ring 43 may mate through one or more tongue and groove joints and may thereby rotate together, locking adjacent pad sets at a fixed angular offset for restricting fluid slippage axially though pad gap 90. For example, as shown in FIGS. 16 and 17, two adjacent pad sets may be offset circumferentially by an angular offset of approximately 45 degrees. Alternatively, other joints may be used, or the central finger ring and clocking ring may be formed as one piece. In another embodiment not shown, central finger ring 47 and clocking ring 43 may slide against each other and not maintain any particular angular offset. For a plunger having 3 pad sets, there may be two clocking pairs of a central finger ring 47 and a clocking ring 43, where all three pad sets rotate together around the mandrel, and where each pair of adjacent pad sets may have a particular angular offset. For example, each pad set in a triple-pad plunger may be clocked at 0, 30, and 60 degrees, or may be clocked at 0, 45, and 90 degrees.
Alternately, in an embodiment not shown, elements 47 and 43 may project fingers into pad cutouts 28 and be fixed on mandrel 30 for retaining arcuate pad 28 without providing pad rotation. Elements 47 and 43 may be fixed to mandrel 30 and have fingers projected axially into pad cutouts 28 such that there is an angular offset of 0 degrees, 45 degrees, or another angular offset amount. Although, in an embodiment not shown, arcuate pads 12 may not rotate around mandrel 30, the entire lift plunger 10 may rotate within the tubing string of the well by incorporation of rhombus-shaped arcuate pads, by the incorporation of spiral grooves in at least one of a top end and a bottom end, or by incorporating both rhombus pads and spiral grooves.

Central finger ring 47 may be identical to the finger rings 47 used near the distal ends of mandrel 30 in order to reduce the unique parts count, or may be uniquely optimized for mating or spacing requirements in the central region. Central collar 53 may preferably be longer than end collar 51 in order to sleeve both finger ring 47 and clocking ring 43. At least two arcuate pads 12 may comprise a pad set. Preferably, four arcuate pads 12 may comprise a pad set. However, other combinations, such as three, five, or six or more pads may be used to accommodate different manufacturing and application requirements, such as using a larger number of pads to accommodate a highly deviated well. Advantageously, providing a lift plunger 10 with rotation of the arcuate pads has the benefit of overcoming one-sided wear, avoiding the developing of wearing stripes on wear surfaces 20, maintaining superior sealing against the inner surface of the tubing string, especially in a highly deviated well, and prolonging the life of the plunger.

In an embodiment, referring now to FIG. 18 through FIG. 24, a lift plunger 10 may comprise two sets of four arcuate pads 12 stacked axially and disposed circumferentially around the mandrel 30 such that wear surfaces 20 cooperate to form a substantially contiguous cylindrical seal against the inner surface of the tubing string 16 (not shown). Top end 34 and bottom end 32 may cap mandrel 30 and attach via mandrel threads 30a. Finger ring 47 may bear rotatably on circumferential surface 36 near the distal ends of mandrel 30 and may project axial finger 47a axially into pad cutout 28 for containing arcuate pad 12 while allowing radial movement under the outward biasing of one or more springs 60. Finger ring 47 may be restrained axially outwardly by top end 34 or bottom end 32, and the combination of finger ring 47, mandrel end 32 or 34, and pad cutout 28 may form a circular guide for enabling rotatable pads by substantially restricting the motion of the arcuate pad to be circumferential around the mandrel axis. Spring 60 may be disposed between spring cavity 62 in the underside of arcuate pad 12 and mandrel 30, and there may be two springs per arcuate pad 12. Alternately, two or more arcuate pads 12 may comprise a pad set. Continuing with FIGS. 18-24, in an embodiment, central finger ring 47 may bear rotatably on circumferential surface 36 between two adjacent pad sets and may project axial finger 47a axially into pad cutout 28 for containing arcuate pad 12 of one pad set while allowing radial movement of arcuate pad 12. Clocking ring 43 may mate with central finger ring 47 such that they rotate together under central collar 53, the clocking ring 43 bearing directly on circumferential surface 36 and projecting axial fingers 47a axially into pad cutouts 28 of the adjacent pad set. The two pad sets may be located axially by the sandwiching of finger ring 47 mated adjacent to clocking ring 43. Central finger ring 47 and clocking ring 43 may each, in combination with pad cutout 28, provide a circular guide for arcuate pads 12, and may thereby enable rotatable pads by substantially restricting the motion of the arcuate pad to be circumferential around the mandrel axis. Bottom end cavity 38 may be formed in bottom end 32 in order to provide greater gas lift.

Referring still to FIGS. 18-24, in an embodiment, the distal end of end collars 51 may be adjacent to top end 34 and bottom end 32, and may be shaped as a cylindrical sleeve enclosing finger ring 47. The central end of end collars 51 may provide a collar lip 52 for enclosing a pad upper end 24 or a pad lower end 22 for limiting outward radial movement of the arcuate pad 12. A central collar 53 may be a cylindrical sleeve enclosing clocking ring 43 and central finger ring 47 and may provide a collar lip 52 on both ends for enclosing pad upper end 24 of one pad set and pad lower end 22 of the adjacent pad set, thereby limiting outward radial movement of arcuate pad 12. Alternatively, an annular lip (not shown) may be disposed directly on the circumferential surface 36 of mandrel 30 to enclose pad upper end 24 or pad lower end 22. Continuing with FIGS. 18-24, in an embodiment, finger ring 47 and clocking ring 43 may contain ring bearing surface 47b rotatably bearing on circumferential surface 36 of mandrel 30. Finger ring 47 may include dado groove 43b mating with dado-tongue 43a of clocking ring 43, and may thereby cause finger ring 47 and clocking ring 43 to rotate together, clocking adjacent pad sets at a fixed angular offset for resisting fluid slippage axially though pad gap 90 (not shown). For example, as shown in FIG. 18, two adjacent pad sets may be offset circumferentially by an angular offset of approximately 45 degrees. Alternately, offsets of 0, 30, or 60 degrees may be chosen. Additionally, joints other than tongue-and-groove may be used, and the central finger ring 47 and clocking ring 43 may be formed as one piece.

With reference to FIGS. 18-25, in an embodiment, a fluid bypass (not shown) for conducting fluid axially through a central portion of the mandrel may be included, as shown in FIGS. 14a and 14b. Alternately, a plurality of spiral grooves (not shown) in at least one of a top end and a bottom end of the mandrel may be included for encouraging rotation of the plunger traveling in a fluid, as shown in FIG. 13. Further, the channel formed by pad gap 90 (not shown) may be oblique to the mandrel axis 31 by a pad slant angle 92 of less than approximately 55 degrees, thereby forming arcuate pad 12 in the shape of a rhombus and encouraging rotation of the arcuate pads, as shown in FIGS. 16, 17, and 25. FIG. 25a illustrates a perspective view of an arcuate pad having a rhombus shape. FIG. 25b illustrates a perspective view of the arcuate pad of FIGS. 25a in which there is a view of a pair of spring cavities. FIG. 25c illustrates a bottom view of the arcuate pad of FIGS. 25a and 25b in which there is a view of the pair of spring cavities.

Referring to FIG. 23, in an embodiment, lift plunger 10 may be assembled in a slide-on manner, starting with attaching a mandrel end 32 or 34, adding finger ring 47 and end collar 51, and may continue with sliding on a first set of arcuate pads 12 and biasing springs 60, followed by adding clocking ring 43 and central finger ring 47 plus central collar 53, and may proceed with positioning a second set of arcuate pads and biasing springs 60, adding finger ring 47 and end collar 51, and may end with attaching the other mandrel end 34 or 32, respectively.

Advantageously, providing a lift plunger 10 with rotatable arcuate pads may have the benefit of overcoming one-sided wear, avoiding the developing of wearing stripes on
wear surfaces 20, maintaining superior sealing against the inner surface of the tubing string, especially in a highly deviated well, and prolonging the life of the plunger.

[0084] Although the above embodiments have been described in language that is specific to certain structures, elements, compositions, and methodological steps, it is to be understood that the technology defined in the appended claims is not necessarily limited to the specific structures, elements, compositions and/or steps described. Rather, the specific aspects and steps are described as forms of implementing the claimed technology. Since many embodiments of the technology can be practiced without departing from the spirit and scope of the invention, the invention resides in the claims herinafter appended.

What is claimed is:

1. A plunger for lifting fluids within a tubing string of a hydrocarbon well, comprising:
   - an elongated mandrel having a mandrel axis and a circumferential surface;
   - at least 2 arcuate pads having each a pad upper end and a pad lower end and disposed circumferentially around the mandrel to form a pad set, each arcuate pad having a wear surface cooperating to form a substantially contiguous cylindrical seal against an inner surface of the tubing string;
   - at least one spring disposed between the mandrel and the arcuate pad for biasing the arcuate pad outwardly radially such that the wear surfaces are movable in contact with the inner surface of the tubing string;
   - at least one circular guide disposed on the mandrel and each engaging a complementary receptacle of the arcuate pad for substantially restricting the motion of the arcuate pad to be circumferential around the mandrel axis;
   - an annular retainer disposed around the mandrel and positioned to enclose one of the pad upper end, the pad lower end, the pad upper end of one pad set and the pad lower end of another pad set, the annular retainer limiting outward radial movement of the arcuate pad; and
   - wherein the at least one circular guide, the complementary receptacles, the springs, and the annular retainers cooperate to allow rotation of the arcuate pads about the mandrel axis while radially biasing the arcuate pads against the inner surface of the tubing string, thereby lifting fluids within the tubing string.

2. The plunger of claim 1, further comprising a bypass for conducting fluid axially through a central portion of the mandrel and comprising an elongated mandrel hollow, a bypass inlet, and a bypass actuator, where the bypass actuator opens the bypass inlet and allows fluid into the mandrel hollow.

3. The plunger of claim 1, further comprising at least two pad sets stacked axially along the mandrel, wherein 4 arcuate pads comprise the pad set, each pad set independently forming a cylindrical seal with the inner surface of the tubing string.

4. The plunger of claim 3, further comprising maintaining an angular offset between a first pad set and a second pad set, where a pad gap between a pad side edge of each of two adjacent arcuate pads forms a channel allowing fluid slippage, the pad gap of the first pad set being circumferentially offset from the pad gap of the second pad set, thereby creating the angular offset limiting fluid slippage.

5. The plunger of claim 1, wherein the annular retainer is a cylindrical sleeve having a collar lip for retaining one of the pad upper end and the pad lower end.

6. The plunger of claim 1, further comprising a plurality of spiral grooves in at least one of a top end and a bottom end of the mandrel for encouraging rotation of the plunger traveling in a fluid.

7. The plunger of claim 1, wherein 4 arcuate pads comprise the pad set and each arcuate pad is shaped as a rhombus for establishing a pad gap oblique to the mandrel axis by a pad slant angle of less than approximately 35 degrees, the pad gap separating a pad side edge of each of two adjacent arcuate pads and providing a channel for fluids to flow between the pad upper end and the pad lower end, thereby encouraging rotation of the arcuate pads traveling in a fluid.

8. The plunger of claim 1, wherein the circular guide comprises a mandrel end capping an end of the mandrel and a finger ring bearing rotatably on the circumferential surface and restrained axially outwardly by the mandrel end, each finger ring projecting a finger axially inwardly into the complementary receptacle at one of the pad upper end and the pad lower end of each arcuate pad, where the complementary receptacle is a pad cutout opening axially outwardly, where the fingers and the pad cutouts retain the arcuate pads while allowing radial movement, and where the annular retainer is an end collar disposed around each finger ring.

9. The plunger of claim 8, further comprising a bypass for conducting fluid axially through a central portion of the mandrel and comprising an elongated mandrel hollow, a bypass inlet, and a bypass actuator, where the bypass actuator opens the bypass inlet and allows fluid into the mandrel hollow.

10. The plunger of claim 8, wherein 4 arcuate pads comprise the pad set and each arcuate pad is shaped as a rhombus for establishing a pad gap oblique to the mandrel axis by a pad slant angle of less than approximately 35 degrees, the pad gap separating a pad side edge of each of two adjacent arcuate pads and providing a channel for fluids to flow between the pad upper end and the pad lower end, thereby encouraging rotation of the arcuate pads traveling in a fluid.

11. The plunger of claim 8, further comprising multiple pad sets and a central finger ring bearing rotatably on the circumferential surface lying between two adjacent pad sets, the central finger ring projecting fingers into the pad cutouts of one pad set, and further comprising a clocking ring mating with the central finger ring such that they rotate together, the clocking ring projecting fingers into the pad cutouts of the adjacent pad set such that both pad sets are clocked at an angular offset for restricting fluid slippage axially through a pad gap between adjacent arcuate pads.

12. The plunger of claim 11, where the annular retainer is a central collar disposed around both the finger ring and the clocking ring and having a collar lip at each end for limiting outward radial movement of the pad upper ends and the pad lower ends.

13. The plunger of claim 11, wherein 4 arcuate pads comprise the pad set.

14. A plunger for lifting fluids within a tubing string of a hydrocarbon well, comprising:
   - an elongated mandrel having a mandrel axis and a circumferential surface;
   - at least 2 arcuate pads having each a pad upper end and a pad lower end and disposed circumferentially around the mandrel to form a pad set, each arcuate pad having a wear surface arcing between two pad side edges and cooperating to form a substantially contiguous cylindrical seal against an inner surface of the tubing string;
at least one spring disposed between the mandrel and the arcuate pad for biasing the arcuate pad outwardly radially such that the wear surfaces are moveably in contact with the inner surface of the tubing string;

an annular retainer disposed around the mandrel and positioned to enclose one of the pad upper end, the pad lower end, the pad upper end of a first pad set and the pad lower end of a second pad set, the annular retainer limiting outward radial movement of the arcuate pad;

a pad gap separating the pad side edges of two adjacent arcuate pads and providing a channel for fluids to flow between the pad upper end and the pad lower end; and

wherein each arcuate pad is shaped as a rhombus for slanting the pad gap oblique to the mandrel axis by a pad slant angle of less than approximately 35 degrees, thereby encouraging rotation of the arcuate pads.

15. The plunger of claim 14, wherein a bypass for conducting fluid axially through a central portion of the mandrel and comprising an elongated mandrel hollow, a bypass inlet, and a bypass actuator, where the bypass actuator opens the bypass inlet and allows fluid into the mandrel hollow.

16. The plunger of claim 14, further comprising at least two pad sets stacked axially along the mandrel, wherein 4 arcuate pads comprise the pad set, each pad set independently forming a cylindrical seal with the inner surface of the tubing string.

17. The plunger of claim 16, further comprising maintaining an angular offset between the first pad set and the second pad set.

18. The plunger of claim 14, wherein the annular retainer is one of a cylindrical sleeve having a collar lip for retaining the arcuate pad, an annular lip disposed on the circumferential surface of the mandrel for retaining the arcuate pad.

19. The plunger of claim 14, further comprising at least one circular guide disposed on the mandrel and each engaging a complementary receptacle of the arcuate pad for substantially restricting the motion of the arcuate pad to be circumferential around the mandrel axis, wherein the at least one circular guide, the complementary receptacles, the springs, and the annular retainers cooperate to allow rotation of the arcuate pads about the mandrel axis while radially biasing the arcuate pads against the inner surface of the tubing string, thereby lifting fluids within the tubing string.

20. The plunger of claim 14, further comprising a plurality of spiral grooves in at least one of a top end and a bottom end of the mandrel for encouraging rotation of the plunger traveling in a fluid.