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(54) **RECIPROCATING PUMP WITH IMPROVED FLUID CYLINDER CROSS-BORE GEOMETRY**

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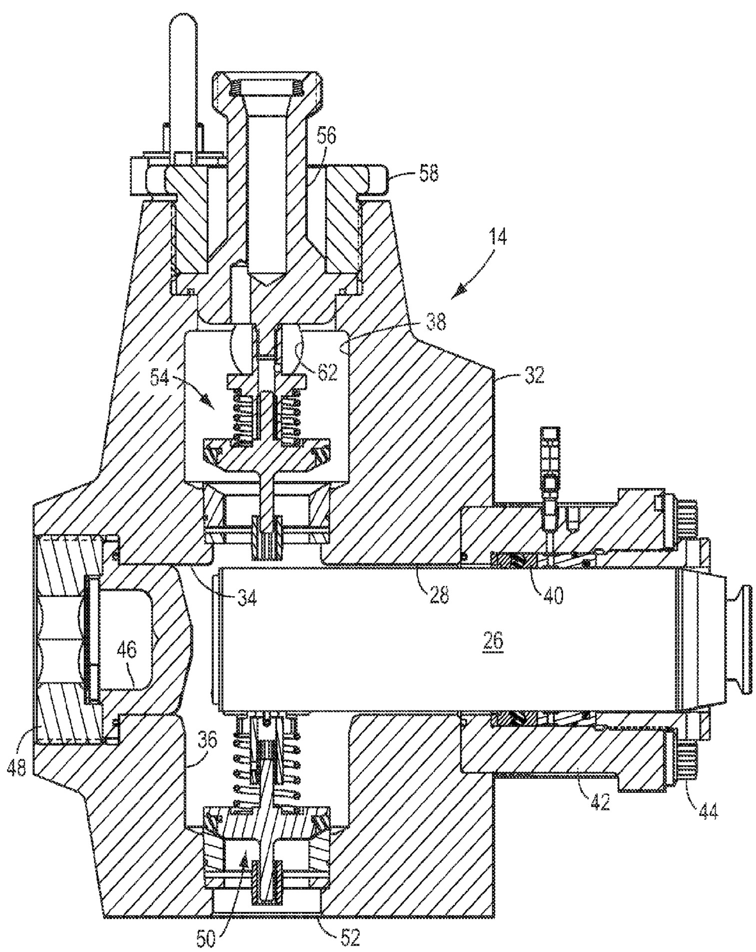
CPC ***F04B 53/16*** (2013.01); ***F04B 19/22*** (2013.01); ***F04B 53/14*** (2013.01); ***F04B 53/10*** (2013.01)

(57) **ABSTRACT**

A reciprocating pump comprising a fluid end housing having a number of plunger sections, each of which includes a plunger bore within which a plunger is slidably received, a suction bore within which a suction valve is positioned, a discharge bore within which a discharge valve is positioned, and a cross bore chamber which is located between said bores and is configured as a surface of revolution. Each of the bores intersects the cross-bore chamber to thereby define a respective cross curve which is spatially separated from each adjacent cross curve. In this manner, the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves.



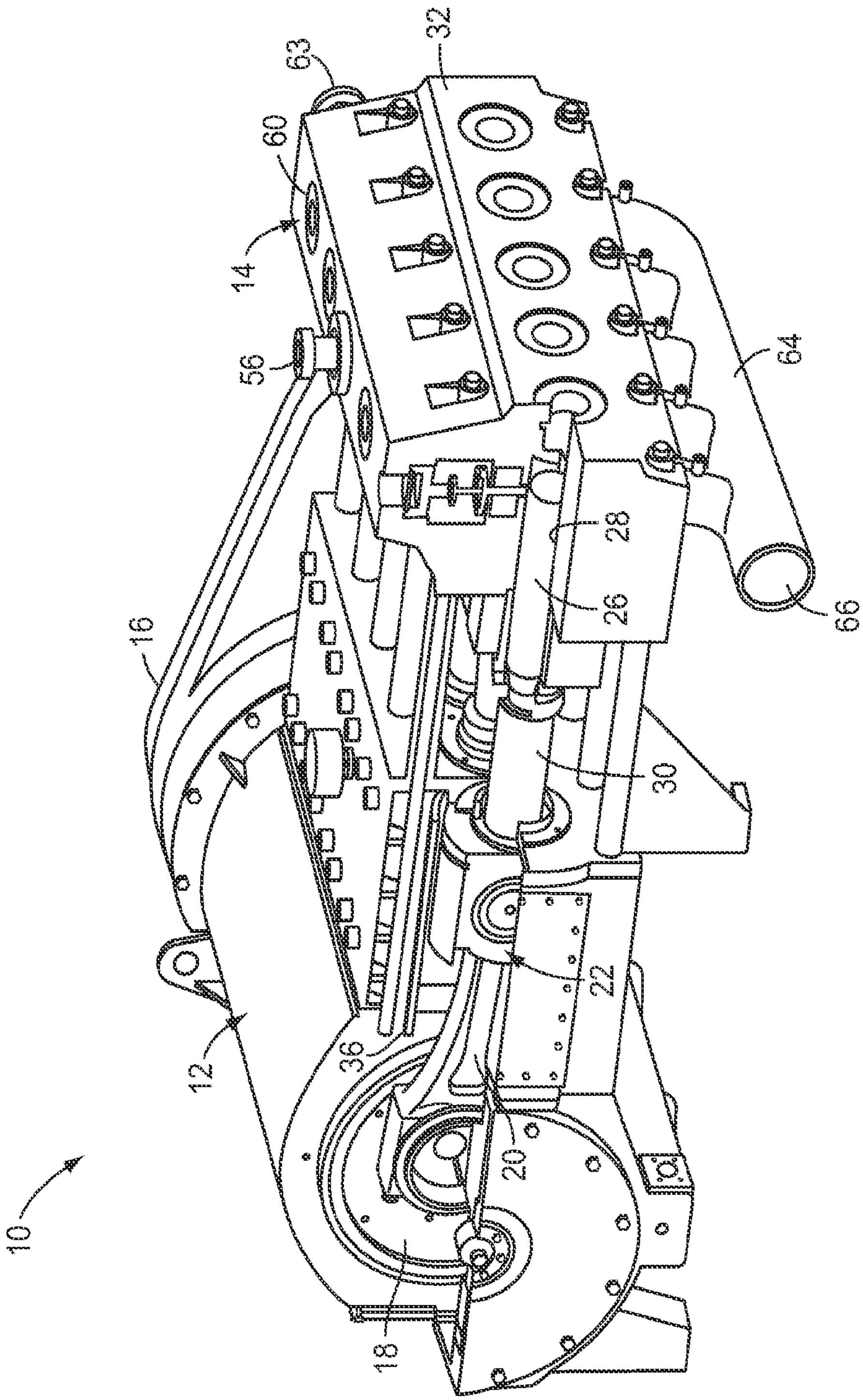


FIG. 1

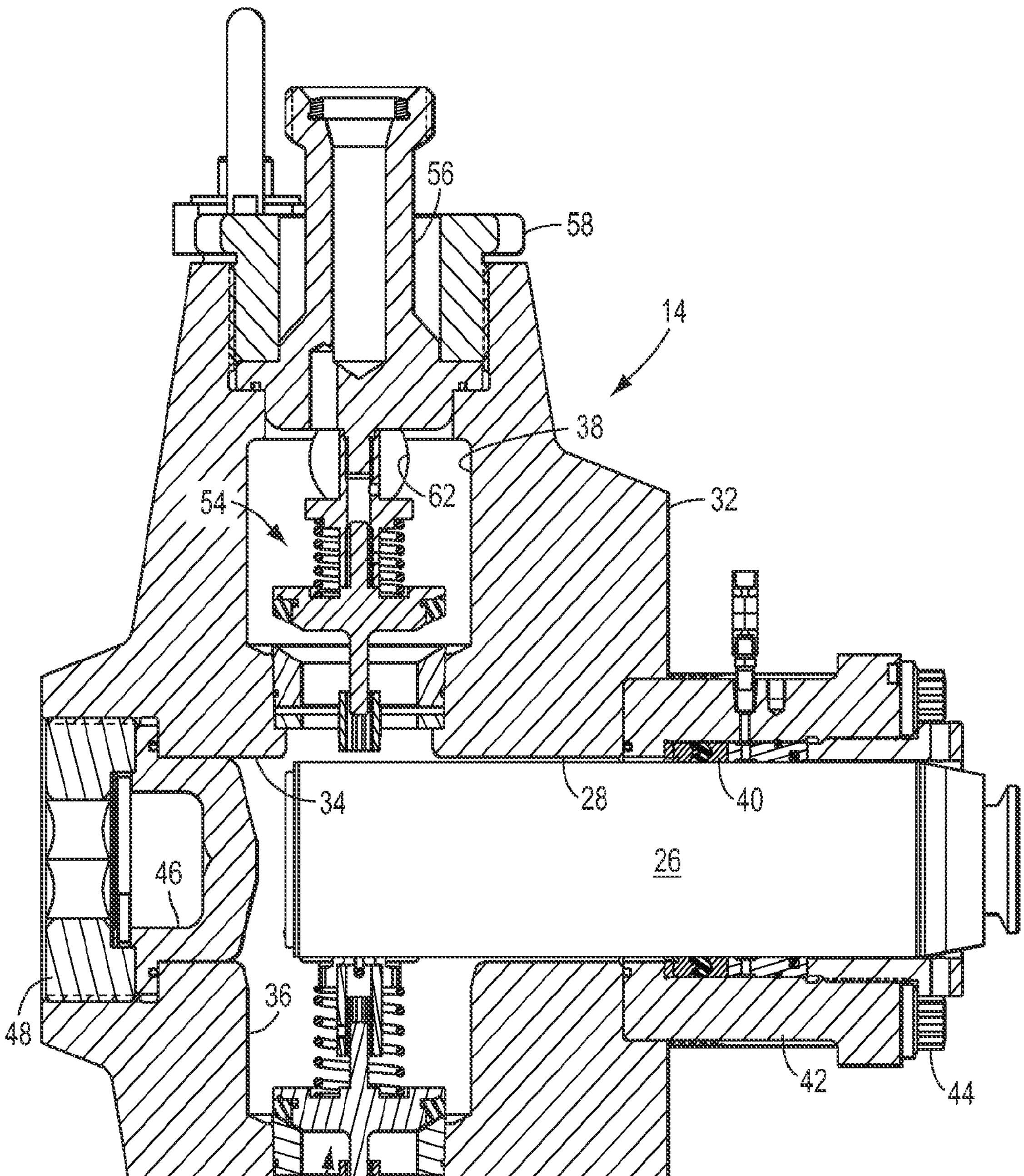


FIG. 2

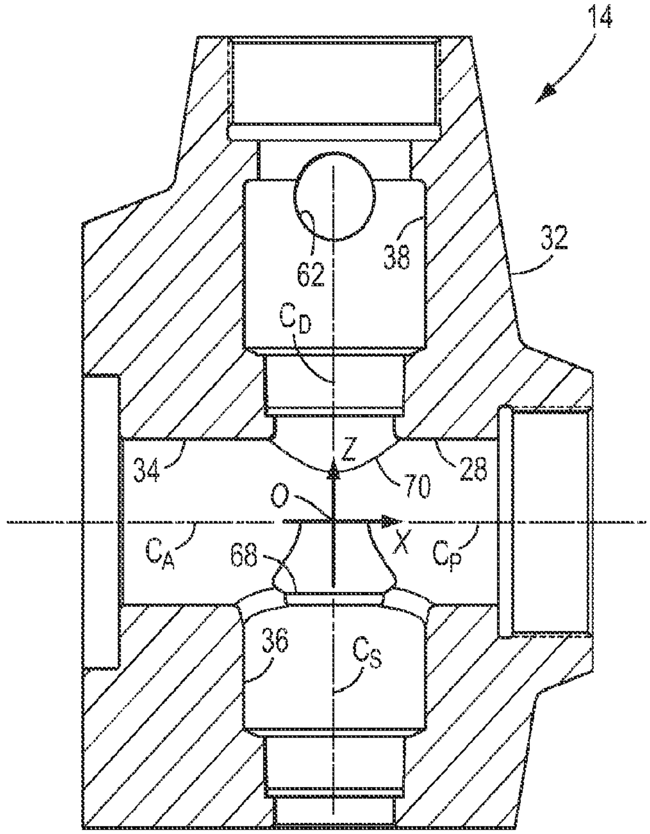

14
32
62
38
C_D
34
Z
70
28
O
X
C_A
68
C_P
36
C_S

FIG. 3

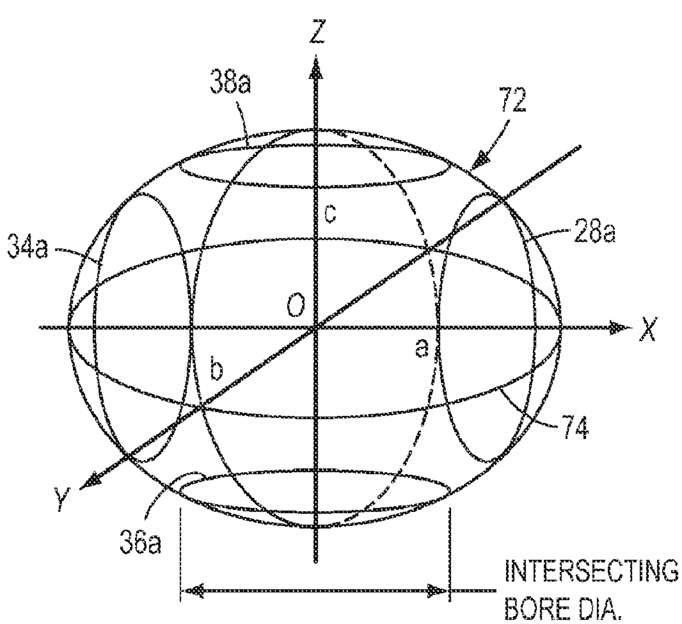

Z
38a
72
c
34a
28a
O
X
b
a
74
Y
36a
INTERSECTING
BORE DIA.

FIG. 4

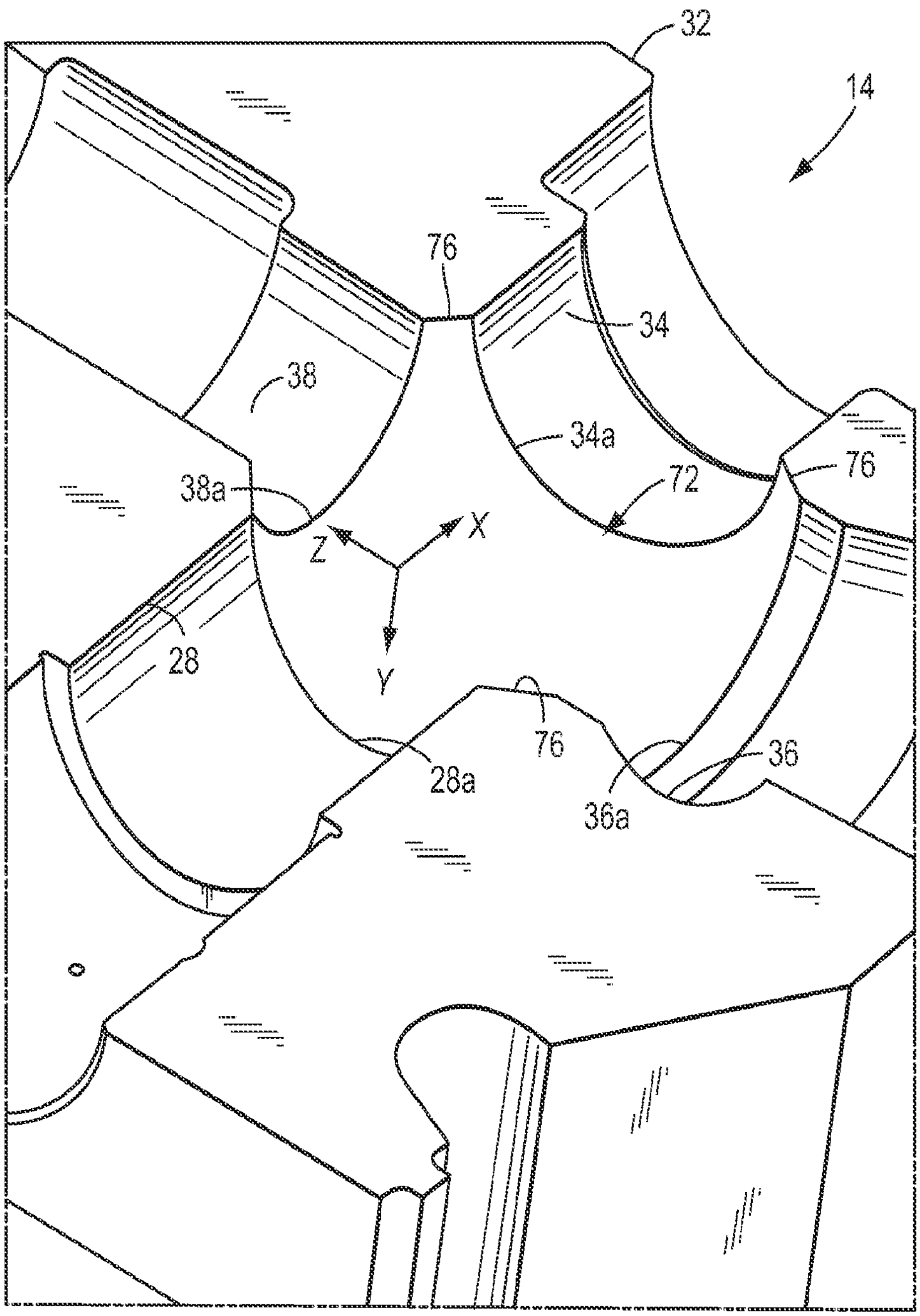


FIG. 5

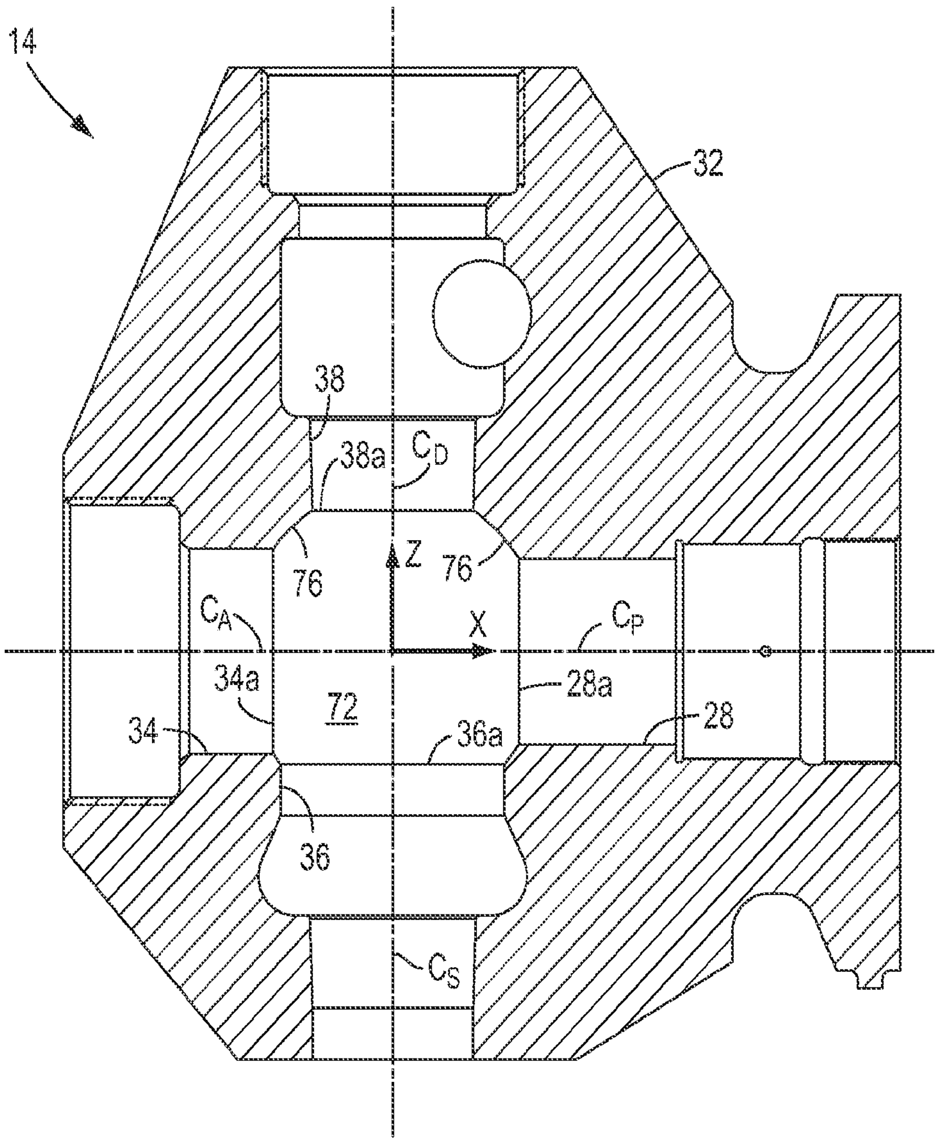


FIG. 6

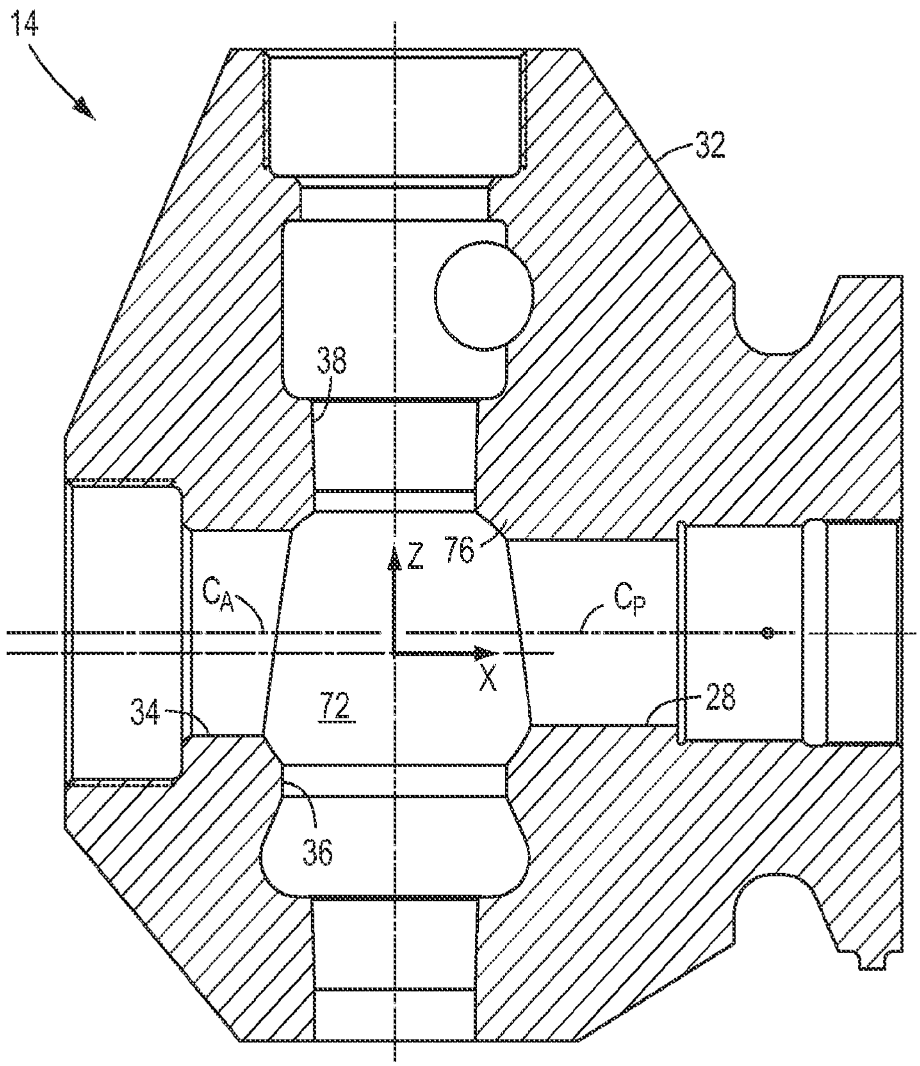


FIG. 7

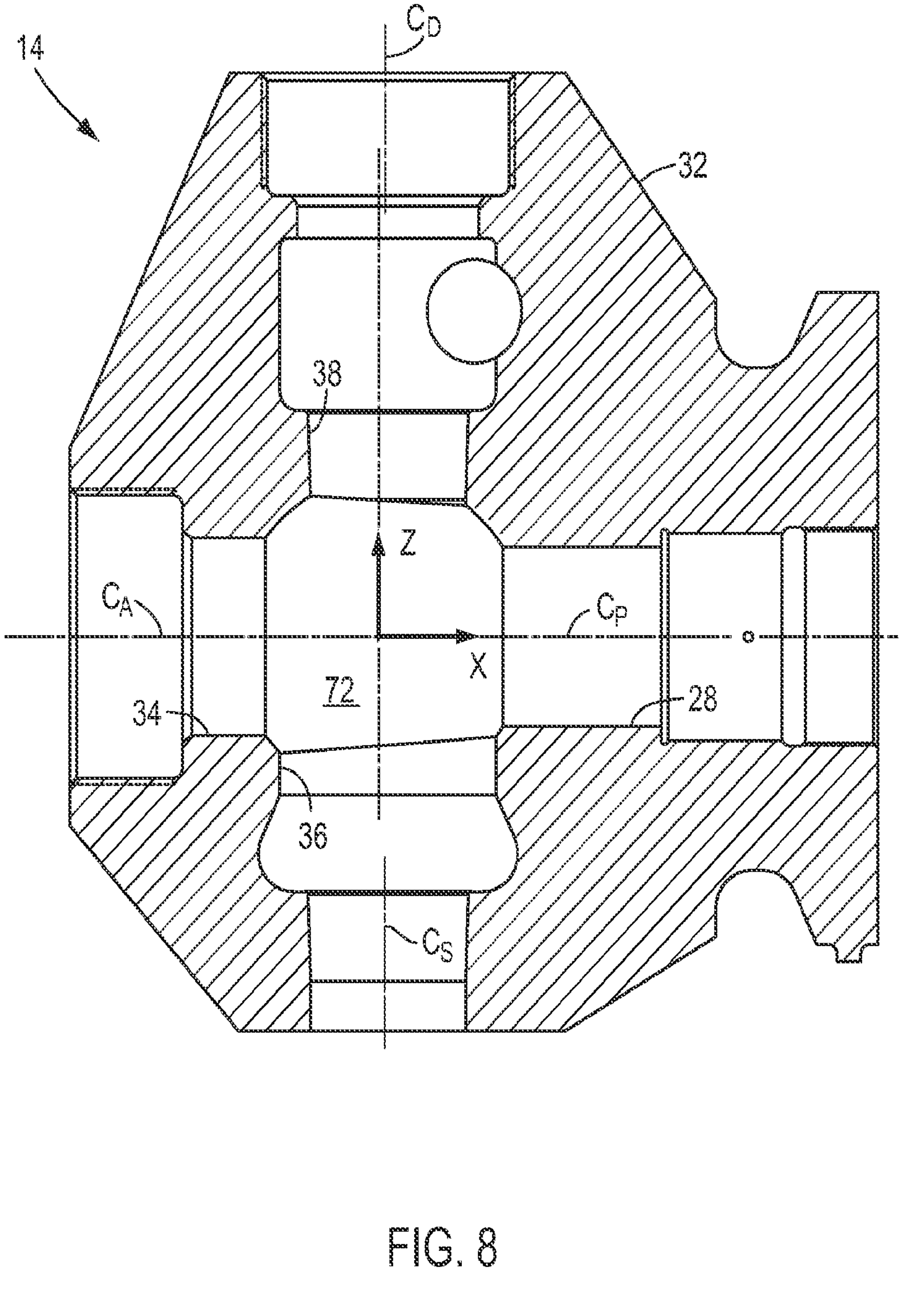


FIG. 8

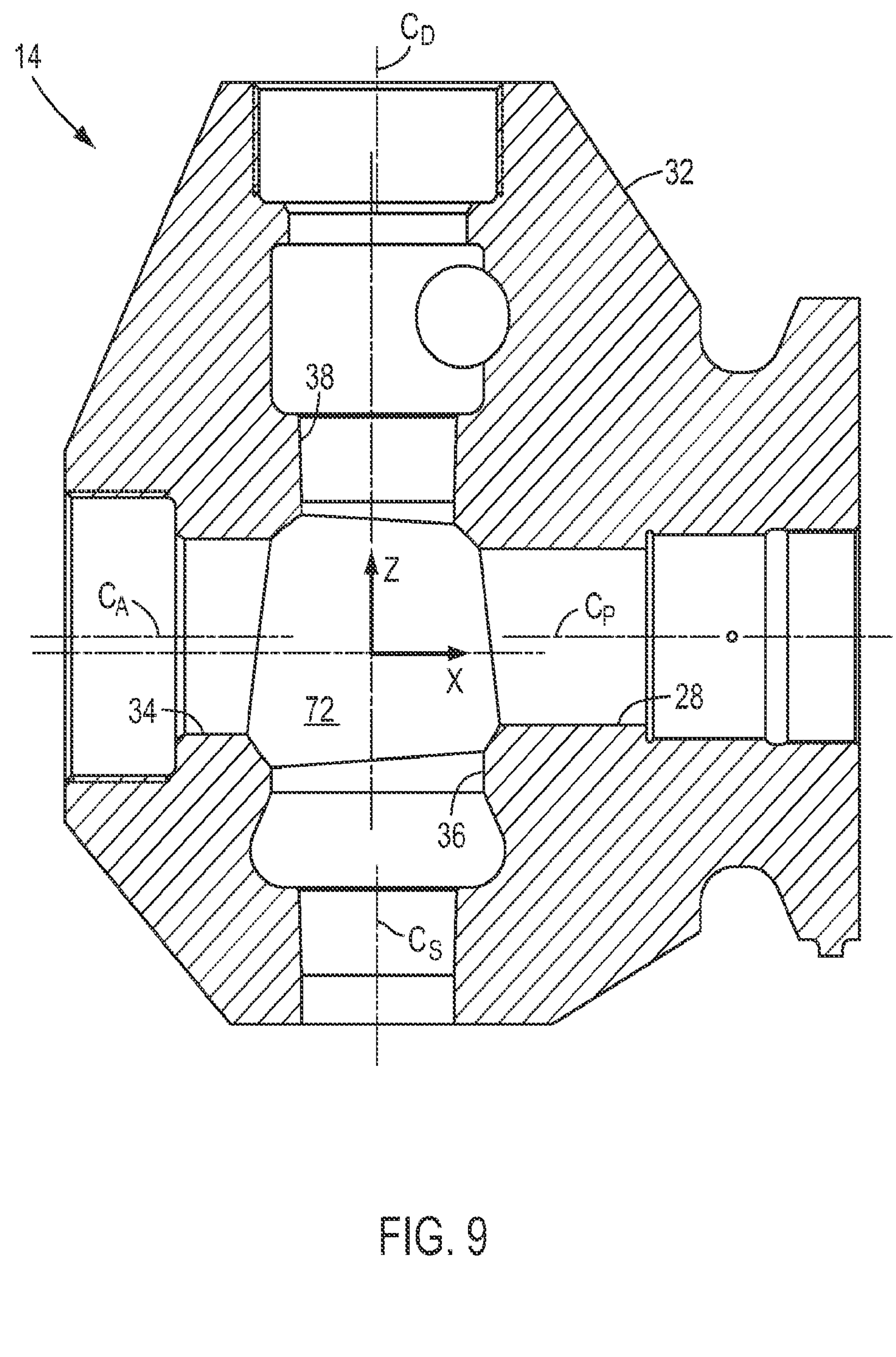


FIG. 9

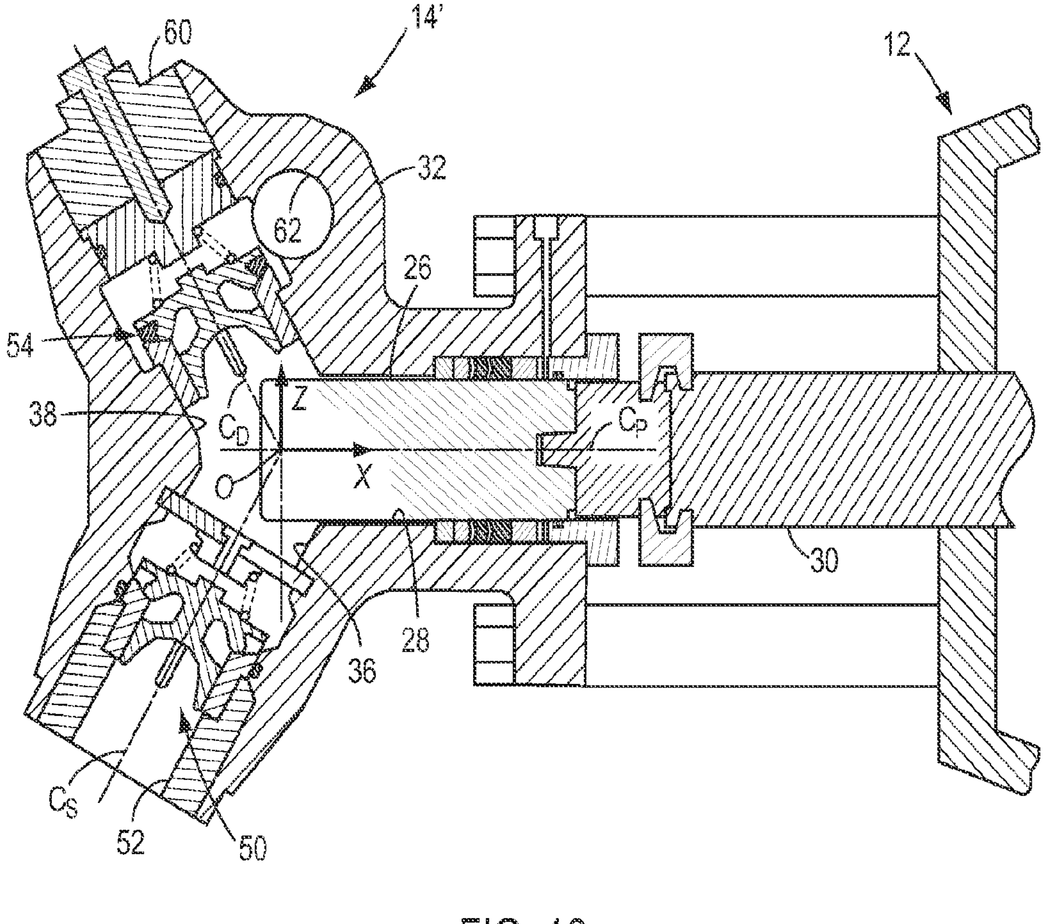


FIG. 10

RECIPROCATING PUMP WITH IMPROVED FLUID CYLINDER CROSS-BORE GEOMETRY

BACKGROUND OF THE INVENTION

[0001] The present invention is related to reciprocating plunger and piston-type pumps which are used, for example, in oil well service operations. In particular, the invention is related to an improved cross-bore geometry for the fluid end of such pumps.

[0002] Plunger pumps for the oilfield industry typically include a power end and a fluid end. The fluid end generally includes a plunger which is positioned in a plunger bore and is reciprocated by the power end, an access bore which is located opposite the plunger bore, a suction valve which is positioned in a suction bore and a discharge valve which is positioned in a discharge bore. In operation, the plunger is reciprocated in the plunger bore to alternately draw fluid into the pump through the suction valve and then force the fluid out of the pump through the discharge valve.

[0003] During operation of the pump, the fluid end is subject to very high frequency and large magnitude pressure pulsations. These pressure pulsations generate large stress concentrations at the intersections of the bores. In cross-bore geometries in which the bore intersections form relatively sharp edges, these stress concentrations may cause fatigue cracks to form in the fluid end proximate the intersections. In some prior art pumps, the intersecting edges of the bores are machined to have quasi radii and chamfered features in an attempt to smooth the bore intersections. Although smoothing the bore intersections in this manner may reduce the stress concentrations to a certain extent, the cross-bore geometries of extreme service pumps remain susceptible to developing excessive stress concentrations due to the limitations imposed by the current configurations of the bore intersections.

SUMMARY OF THE INVENTION

[0004] In accordance with the present invention, these and other limitations in the prior art are overcome by providing a reciprocating pump comprising a fluid end housing having a number of plunger sections, each plunger section including a plunger bore within which a plunger is slidably received, a suction bore within which a suction valve is positioned, a discharge bore within which a discharge valve is positioned, and a cross bore chamber which is located between said bores and is configured as a surface of revolution. Each of said bores intersects the cross-bore chamber to thereby define a respective cross curve which is spatially separated from each adjacent cross curve. In this manner, the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves.

[0005] In accordance with one embodiment of the invention, the cross-bore chamber is configured as an ellipsoid. In this embodiment, the ellipsoid may comprise a first axis which is coaxial with a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is coaxial with a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore.

[0006] In accordance with another embodiment of the invention, each plunger section further comprises an access bore which intersects the cross-bore chamber to thereby define a corresponding cross curve that is spatially separated from each adjacent cross curve. In this manner, the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves. In this embodiment, the cross-bore chamber may be configured as an ellipsoid. In addition, the access bore may be generally aligned with the plunger bore and the suction bore may be generally aligned with the discharge bore, and the access and plunger bores may be oriented at an angle of generally ninety degrees relative to the suction and discharge bores. Also, the ellipsoid may comprise a first axis which is coaxial with a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is coaxial with a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore.

[0007] In accordance with a further embodiment of the invention, the plunger bore, the suction bore and the discharge bore are oriented at an angle of approximately 120 degrees relative to each other. In this embodiment, the ellipsoid may comprise a first axis which is coaxial with a centerline of the plunger bore and a center point which is located at an intersection of the plunger bore, the suction bore and the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is coaxial with a centerline of the plunger bore and a center point which is offset from an intersection of the plunger bore, the suction bore and the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is parallel to but offset from a centerline of the plunger bore and a center which is located at an intersection of the plunger bore, the suction bore and the discharge bore. Alternatively, the ellipsoid may comprise a first axis which is parallel to but offset from a centerline of the plunger bore and a center which is offset from an intersection of the plunger bore, the suction bore and the discharge bore.

[0008] The present invention is also directed to a method of reducing stress concentrations in a fluid end housing of a reciprocating pump, the fluid end housing having a number of plunger sections, each plunger section including a plunger bore within which a plunger is slidably received, a suction bore within which a suction valve is positioned and a discharge bore within which a discharge valve is positioned. The method comprises forming a cross-bore chamber between said bores, said cross-bore chamber being configured as a surface of revolution, wherein each of said bores intersects the cross-bore chamber to thereby define a respective cross curve which is spatially separated from each adjacent cross curve. In this manner, the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves. In accordance with one aspect of this embodiment, the cross-bore chamber may be configured as a spheroid.

[0009] Thus, in accordance with the present invention an improved cross-bore geometry is obtained by creating a cross-bore chamber at the intersection of the plunger bore, the suction bore, the discharge bore and, if present, the access bore. The cross-bore chamber is configured as a surface of revolution which is created by rotating a two-dimensional curve around a reference axis. For example, the cross-bore chamber may be configured as an ellipsoid, a particular case of which is a sphere. By configuring the cross-bore chamber as a surface of revolution such as an ellipsoid, the cross-bore chamber provides a single, smooth contiguous connecting surface between the bores. As a result, the stress concentrations in the cross-bore geometry are significantly reduced, and the fluid end is therefore less susceptible to failure.

[0010] These and other objects and advantages of the present invention will be made apparent from the following detailed description, with reference to the accompanying drawings. In the drawings, the same reference numbers are used to denote similar components in the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a perspective, partial cut-away view of a prior art plunger pump in which the cross-bore geometry of the present invention may be incorporated;

[0012] FIG. **2** is a cross sectional view of the fluid end of the plunger pump shown in FIG. **1**;

[0013] FIG. **3** is a cross sectional view similar to FIG. **2** but with the internal components of the fluid end removed for clarity;

[0014] FIG. **4** is a schematic representation of the cross bore geometry in accordance with one embodiment of the present invention;

[0015] FIG. **5** is a perspective, cut-away view of an embodiment of a fluid end of the present invention having an illustrative cross bore geometry;

[0016] FIG. **6** is a cross sectional view of the fluid end shown in FIG. **5**;

[0017] FIGS. **7-9** are cross sectional views of additional embodiments of fluid ends having differing illustrative cross-bore geometries; and

[0018] FIG. **10** is a cross sectional view of another embodiment of a fluid end in which the cross-bore geometry of the present invention may be incorporated.

DETAILED DESCRIPTION OF THE INVENTION

[0019] An example of a prior art plunger pump in which the cross-bore geometry of the present invention may be incorporated is shown in FIG. **1**. As described more fully in U.S. Pat. No. 7,610,847, which is hereby incorporated herein by reference, the plunger pump **10** comprises a power end **12** and a fluid end **14**. The power end **12** includes a gear reducer assembly **16** which is driven by a suitable motor (not shown). The gear reducer assembly **16** drives a crankshaft **18**. The crankshaft **18** is rotatably connected to one end of a connecting rod **20**, the opposite end of which is pivotally connected to a crosshead **22** that is supported for linear movement in a corresponding guide bore **24**. The fluid end **14** includes a number of plungers **26** (only one of which is shown in FIG. **1**), each of which is slidably mounted in a respective plunger bore **28** and is connected to a respective crosshead **22** by a plunger rod **30**. In operation, rotary motion of the crankshaft **18** is converted by the connecting rod **20** into linear reciprocating motion of the crosshead **22**, which in turn reciprocates the plunger **26** in the plunger bore **28**.

[0020] The fluid end **14** comprises a laterally extending housing **32** having a number of plunger sections (in this case five) which are each aligned with a corresponding plunger **26**. The middle plunger section is shown in greater detail in FIGS. **2** and **3**. With the exception noted below, the middle plunger section is similar to the remaining plunger sections. As described more fully in U.S. Pat. No. 7,681,589, which is hereby incorporated herein by reference, the middle plunger section includes a cross bore arrangement comprising the plunger bore **28**, an access bore **34** which is generally aligned with the plunger bore, a suction bore **36** which is generally perpendicular to the plunger bore, and a discharge bore **38** which is generally aligned with the suction bore.

[0021] The plunger **26** is positioned in the plunger bore **28** and is sealed thereto by, e.g., an annular packing **40**, which in the embodiment shown in FIG. **2** is mounted in a stuffing box **42** that is secured to the housing **32** by a number of cap screws **44**. The access bore **34** is sealed by a plug **46** which is secured to the housing **32** by a first retainer nut **48**. A suction valve **50** is positioned in the suction bore **36** between the plunger bore **28** and an inlet port **52**. A discharge valve **54** is positioned in the discharge bore **38** between the plunger bore **28** and a pressure tap fitting **56** which is secured in the discharge bore by a second retainer nut **58**. The discharge bores **38** of the remaining bore sets are sealed by plugs **60** (FIG. **1**) similar to the plug **48** (FIG. **2**), and all of the discharge bores are fluidly connected via a lateral bore **62** to an outlet coupling **63** (FIG. **1**). In this manner, all the fluid pumped through the several plunger sections will be directed through the lateral bore **62** and exit the pumping unit **10** through the outlet coupling **63**.

[0022] As shown in FIG. **1**, the inlet ports **52** of the several plunger sections are connected to an inlet manifold **64** having a pump inlet **66** which is connectable to, e.g., a source of well service fluid (not shown). In operation of the plunger pump **10**, the plungers **26** are reciprocated by the power end **12** in the manner described above. During the suction stroke of each plunger **26**, the suction valve **50** is forced open and fluid is drawn through the suction bore **36** and into the plunger bore **28**. During the discharge stroke of each plunger **26**, the suction valve **50** is forced closed and the fluid in the plunger bore **28** is forced through the discharge valve **54** and the outlet coupling **63**. Further details of the operation of the suction valve **50** and the discharge valve can be found in the aforementioned U.S. Pat. No. 7,681,589.

[0023] The cross bore arrangement of each plunger section is shown more clearly in FIG. **3**, which is similar to FIG. **2**

but with the internal components of the plunger section removed for clarity. As shown in FIG. **3**, the plunger bore **28** and the access bore **34** comprise respective centerlines C_P and C_A which are coaxial along an axis X, and the suction bore **36** and the discharge bore **38** comprise respective centerlines C_S and C_D which are coaxial along an axis Z that is perpendicular to the axis X. In this embodiment of the fluid end **14**, the suction bore **36** intersects the plunger bore **28** along a first curve **68**, and the discharge bore **38** intersects the plunger bore along a second curve **70**. As may be seen in FIG. **3**, the curves **68**, **70** define relatively sharp edges between the intersecting bores.

[0024] During operation of the pump **10**, the fluid end **14** is subject to very high frequency and large magnitude pressure pulsations. These pressure pulsations generate large stress concentrations at the bore intersections. In cross-bore geometries in which the bore intersections form relatively sharp edges, these stress concentrations may cause fatigue cracks to form in the housing proximate the intersections. Traditionally, quasi radii and chamfers have been applied to the bore intersections using hand tools to obtain some semblance of smoothness. With the advent of robotics and multi-axis machines, these features can be machined programmatically. Although smoothing the bore intersections in this manner may reduce the stress concentrations to a certain extent, the cross-bore geometries of extreme service pumping units remain susceptible to developing excessive stress concentrations due to the limitations imposed by the current configurations of the bore intersections.

[0025] According to the present invention, an improved cross-bore geometry has been developed which greatly reduces the stress concentrations that can lead to fatigue cracks in the fluid end originating at and propagating from the bore intersections. The improved cross-bore geometry is obtained by creating a cross-bore chamber at the intersection of the plunger bore, the access bore, the suction bore and the discharge bore. The characteristics of the cross-bore chamber will be described with reference to the schematic representation shown in FIG. **4**. The cross-bore chamber, generally **72**, is configured as a surface of revolution which is created by rotating a two-dimensional curve **74** around one of the X, Y or Z axes. In this regard, the X, Y and Z axes are defined as the reference axes for the surface of revolution. Although in certain embodiments of the invention the X axis may be coaxial with one or both of the plunger bore centerline C_P and the access bore centerline C_A and the Z axis may be coaxial with one or both of the suction bore centerline C_S and the discharge bore centerline C_D, these axes do not necessarily have to be aligned with any of the bore centerlines.

[0026] The two-dimensional curve **74** can have any practical configuration, provided that it comprises a diameter which is greater than the diameter of the largest of the plunger bore **28**, the access bore **34**, the suction bore **36** and the discharge bore **38**. In the specific embodiment of the invention illustrated in FIG. **4**, the curve **74** is an ellipse which is centered at the origin O of the X, Y and Z axes. Thus, the surface of revolution defining the cross-bore chamber **72** has the general shape of an ellipsoid which is centered about the origin O and is created by rotating the ellipse **74** about the X axis. In the context of the present invention, however, the ellipsoid may have any configuration which is defined by the following standard equation:

$$x^2/a^2+y^2/b^2+z^2/c^2=1,$$

where a, b and c are the respective lengths of the semi-principal axes of the ellipsoid. For example, the cross-bore chamber **72** may be configured as a sphere by making a=b=c.

[0027] Referring still to FIG. **4**, the intersection of each of the plunger bore **28**, the access bore **34**, the suction bore **36** and the discharge bore **38** with the cross-bore chamber **72** defines a respective cross curve **28***a*, **34***a*, **36***a* and **38***a*. The particular shape of each cross curve will of course depend on the shape of the surface of revolution which defines the cross-bore chamber **72**. As may be seen in FIG. **4**, by configuring the cross-bore chamber **72** as a surface of revolution such as an ellipsoid, the cross-bore chamber provides a single, smooth contiguous connecting surface between each of the cross curves. This single, smooth contiguous connecting surface is created by virtue of the fact that, rather than intersecting each other, the plunger bore **28**, the access bore **34**, the suction bore **36** and the discharge bore **38** intersect the cross-bore chamber **72**. Thus, in the present invention the sharp edge formed by the intersection of, e.g., the discharge bore with the plunger bore, is eliminated. Instead, the smooth contiguous connecting surface formed by the cross-bore chamber **72** extends around and between the cross curves **28***a*, **34***a*, **36***a* and **38***a*. As a result, the stress concentrations in the cross-bore geometry are significantly reduced, and the fluid end is therefore less susceptible to fatigue crack formation.

[0028] Referring to FIGS. **5** and **6**, an embodiment of the invention is shown in which the cross-bore chamber **72** comprises a spherical configuration. In this embodiment, the plunger bore centerline C_P and the access bore centerline C_A are coaxial with the X axis and the suction bore centerline C_S and the discharge bore centerline C_D are coaxial with the Z axis. As may be seen especially in FIG. **5**, the spherical configuration of the cross-bore chamber **72** forms a single, smooth contiguous connecting surface **76** between and around the cross curves **28***a*, **34***a*, **36***a* and **38***a*. In this embodiment, the bore with the largest diameter is the suction bore **36**, and the sphere defining the cross-bore chamber **72** comprises a diameter which is larger than the diameter of the suction bore. In this as in other embodiments of the invention, the shape and size of the surface of revolution which is used to form the cross-bore chamber **72** may be determined empirically for a particular cross-bore geometry in order to provide desired stress and flow characteristics for the fluid end.

[0029] Further illustrative and non-limiting embodiments of the cross bore geometry of the present invention are shown in FIGS. **7-9**. The cross bore geometry shown in FIG. **7** is similar to that shown in FIG. **6**. In the embodiment shown in FIG. **7**, however, the X axis is offset from the plunger bore centerline C_P and the access bore centerline C_A, which in this case are coaxial. In this example, where the cross-bore chamber **72** is defined by a sphere having a diameter of 8.50", the X axis is offset in the Z direction 0.50" from the plunger bore centerline C_P toward the suction bore **36**.

[0030] In the embodiment of the cross-bore geometry shown in FIG. **8**, the X axis is coaxial with the plunger bore centerline C_P and the access bore centerline C_A, but the Z axis is offset from the suction bore centerline. C_S and the discharge bore centerline C_D, which in this instance are coaxial. In this example, where the cross-bore chamber **72** is defined by a sphere having a diameter of 8.50", the Z axis is offset in the X direction 0.20" from the discharge bore centerline C_D toward the access bore **34**.

[0031] In the embodiment of the cross-bore geometry shown in FIG. **9**, the X axis is offset from the plunger bore centerline C_P and the access bore centerline C_A, which in this instance are coaxial, and the Z axis is offset from the suction bore centerline C_S and the discharge bore centerline C_D, which in this case are also coaxial. In this example, where the cross-bore chamber **72** is defined by a sphere having a diameter of 8.50", the X axis is offset in the Z direction 0.50" from the plunger bore centerline C_P toward the suction bore **36**, and the Z axis is offset in the X direction 0.20" from the discharge bore centerline C_D toward the access bore **34**.

[0032] Another example of a fluid end in which the cross-bore geometry of the present invention may be incorporated is shown in FIG. **10**. The fluid end of this embodiment, generally **14'**, is described more fully in U.S. Pat. No. 8,147,227, which is hereby incorporated herein by reference. As shown in FIG. **10**, the fluid end **14'** comprises a Y-shaped cross bore arrangement in which the access bore is omitted and the plunger bore **26**, the suction bore **36** and the discharge bore **38** are oriented approximately 120° from each other.

[0033] In accordance with the present invention, a cross-bore chamber (not shown) may be machined into the fluid end to provide the advantages described above. As in the previous embodiments, the cross-bore chamber may comprise a surface of revolution, such as an ellipsoid, which is centered at the origin O of the X, Y and Z reference axes. In addition, the X axis may be either aligned with or offset from the plunger bore centerline C_P, and the origin O of the reference axes may be located at or offset from the intersection of the plunger bore centerline C_P, the suction bore centerline C_S and the discharge bore centerline C_D.

[0034] It should be recognized that, while the present invention has been described in relation to the preferred embodiments thereof, those skilled in the art may develop a wide variation of structural and operational details without departing from the principles of the invention. Therefore, the appended claims are to be construed to cover all equivalents falling within the true scope and spirit of the invention.

We claim:

1. In a reciprocating pump comprising a fluid end housing having a number of plunger sections, each plunger section including a plunger bore within which a plunger is slidably received, a suction bore within which a suction valve is positioned and a discharge bore within which a discharge valve is positioned, the improvement comprising a cross bore chamber which is located between said bores and is configured as a surface of revolution, wherein each of said bores intersects the cross-bore chamber to thereby define a respective cross curve which is spatially separated from each adjacent cross curve, whereby the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves.

2. The pump of claim **1**, wherein the cross-bore chamber is configured as an ellipsoid.

3. The pump of claim **2**, wherein the ellipsoid comprises a first axis which is coaxial with a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore.

4. The pump of claim **2**, wherein the ellipsoid comprises a first axis which is coaxial with a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore.

5. The pump of claim **2**, wherein the ellipsoid comprises a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore.

6. The pump of claim **2**, wherein the ellipsoid comprises a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore.

7. The pump of claim **1**, wherein each plunger section further comprises an access bore which intersects the cross-bore chamber to thereby define a corresponding cross curve that is spatially separated from each adjacent cross curve, whereby the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves.

8. The pump of claim **7**, wherein the cross-bore chamber is configured as an ellipsoid.

9. The pump of claim **8**, wherein the access bore is generally aligned with the plunger bore and the suction bore is generally aligned with the discharge bore, and wherein the access and plunger bores are oriented at an angle of generally ninety degrees relative to the suction and discharge bores.

10. The pump of claim **9**, wherein the ellipsoid comprises a first axis which is coaxial with a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore.

11. The pump of claim **9**, wherein the ellipsoid comprises a first axis which is coaxial with a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore.

12. The pump of claim **9**, wherein the ellipsoid comprises a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is coaxial with at least one of a centerline of the suction bore and a centerline of the discharge bore.

13. The pump of claim **9**, wherein the ellipsoid comprises a first axis which is parallel to but offset from a centerline of the plunger bore and a second axis which is parallel to but offset from at least one of a centerline of the suction bore and a centerline of the discharge bore.

14. The pump of claim **2**, wherein each of said bores is oriented at an angle of approximately 120 degrees relative to each other bore.

15. The pump of claim **14**, wherein the ellipsoid comprises a first axis which is coaxial with a centerline of the plunger bore and a center point which is located at an intersection of the plunger bore, the suction bore and the discharge bore.

16. The pump of claim **14**, wherein the ellipsoid comprises a first axis which is coaxial with a centerline of the plunger bore and a center point which is offset from an intersection of the plunger bore, the suction bore and the discharge bore.

17. The pump of claim **14**, wherein the ellipsoid comprises a first axis which is parallel to but offset from a centerline of the plunger bore and a center which is located at an intersection of the plunger bore, the suction bore and the discharge bore.

18. The pump of claim **14**, wherein the ellipsoid comprises a first axis which is parallel to but offset from a centerline of the plunger bore and a center which is offset from an intersection of the plunger bore, the suction bore and the discharge bore.

19. A method of reducing stress concentrations in a fluid end housing of a reciprocating pump, the fluid end housing having a number of plunger sections, each plunger section including a plunger bore within which a plunger is slidably received, a suction bore within which a suction valve is positioned and a discharge bore within which a discharge valve is positioned, the method comprising:

forming a cross-bore chamber between said bores, said cross-bore chamber being configured as a surface of revolution;

wherein each of said bores intersects the cross-bore chamber to thereby define a respective cross curve which is spatially separated from each adjacent cross curve;

whereby the cross-bore chamber defines a single, contiguous surface which extends around and between all of said cross curves.

20. The method of claim **19**, wherein said cross-bore chamber is configured as a spheroid.

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