DUAL ACTING ROD PISTON CONTROL SYSTEM

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FIELD OF THE INVENTION

[0001] The field of the invention is subterranean hydraulic pressure control systems for tools and more particularly control systems using rod pistons which are double acting for shortening overall tool length.

BACKGROUND OF THE INVENTION

[0002] On many occasions tools that are located far underground such as in a wellbore need to be operated at predetermined times from the surface. This is typically accomplished by running small hydraulic lines adjacent a producing tubing string and connecting the lines to one or more operating pistons that are in turn connected to a movable component in the tool. In the case of a downhole isolation valve, for example, the valve can be selectively operated between an open and a closed position from the surface. Options are possible such as for chokes where intermediate positions are also possible between fully open and fully closed.

[0003] There are numerous design criteria that affect the design of a control system for a particular application. In most applications space is at a premium in a downhole location and the more space allotted to the control system the less space remains for a through passage in the tool such as a valve. There are also issues of overall tool length as well as a choice between using an annular piston or one or more rod pistons. While certain options address some criteria favorably, they also create issues in other criteria that makes such an option more expensive or in some cases impractical. For example, an annular piston can be used in a downhole valve that can be fairly short and double acting as illustrated in US Publication 2008/0110632. The problem is that the annular piston 26 takes up a lot of space and makes the use of rod piston(s) more practical. Annular pistons experience large seal friction due to the size of the seals that are associated with them. Rod pistons have very small seals and correspondingly less seal friction that has to be overcome with the hydraulic system.

[0004] One way to employ rod pistons is in opposed pairs where each bank of rod pistons is single acting. It is important to keep in mind that it is undesirable to have manifolds of control lines on the exterior of a tool housing to

reach individual rod piston chambers. What is frequently done is that two housing components are designed to create an annular chamber that communicates with one side of a bank of rod pistons. To enable reverse motion, another bank of rod pistons is oppositely oriented with its own control line connection so that depending on which control line is pressurized, the downhole tool component is urged to move in opposite directions. In an improvement to the design of US Publication 2008/0110632 the annular piston 26 was replaced with pairs of opposed rod pistons as described in US Application Serial Number 12/054,809 filed March 25, 2008. FIG. 1 illustrates a simplified version of the control system used in that application to facilitate understanding of the present invention.

[0005] In an application for turning a ball 90 degrees between and open and a closed position, there was shown in that application a shifting slide that engages the turning ball in an offset manner where the ball was pinned for rotation about its center. As shown in FIG. 1, the ball **10** is connected off center at **12** by a shifting slide **14**. The ball **10** is also pinned about its center for rotation and that connection is not shown to make the drawing more simple. An annular chamber **16** is formed as threads **18** and **20** are made up to connect components **22** and **24**. A control line connection **26** directs fluid pressure into chamber **16** and from there to the individual rod piston bores such as **28** and **30**. Pistons such as **32** and **34** each have piston seals such as **36** and **38** such that pressure applied at control line connection **26** will shift all the upper rod pistons such as **32** and **34** in tandem. Since all the pistons such as **32** and **34** are connected to the slide **14**, actuating the upper rod pistons turns the ball **10** 90 degrees. There is also provided a mirror image array of lower pistons **40** and **42** connected on an opposite end of the slide **14** and is actuated to move in the opposite direction as pistons **32** and **34** when hydraulic pressure is applied at connection **44** that leads into an annular chamber **46** that communicates with all the piston bores such as **48** and **50**. Since the pistons **40** and **42** have seals **52** and **54** pressure applied at connection **44** results in opposed ball **10** movement than pressure applied at connection **26**.

[0006] One issue with this design is that it makes the overall tool length very long because there are duplicated sets of opposed pistons that are single acting, while being disposed end to end for design simplicity and to avoid wasting space that is needed by other components.

[0007] The problem with trying to make rod pistons double acting is illustrated in FIG. 2. Solving this problem is one of the objectives of the present invention. Before going into the details of why the FIG. 2 design is a problem it is important to again emphasize that external manifolds of control lines that access every rod piston bore from the outside of the tool housing are frowned upon because they can very easily be bent, damaged or even sheared off when running the tool to the desired position downhole through surrounding tubulars with minimal clearance. To make rod pistons double acting before the present invention was developed, the standard thinking was that there would need to be another housing connection that could define a second annular chamber as shown in FIG. 2. This meant that the piston bore would straddle two threaded components. The problem that arises from such a design is that there is no reliable way to ensure that the portions in a single piston bore in two abutting housing pieces create a second annular chamber that would in fact be in alignment so that the piston would not get into a bind. FIG. 2 illustrates this problem. As before there is an upper annular chamber **16'** made by threads of adjoining housing pieces **22'** and **24'**. However, to create a second annular chamber **56** a new housing component **58** will have to be connected to component **22'** at threads **60** and **62**. To make such a design work the upper portion of the piston bore **64** in component **22'** would have to perfectly align with the lower portion of the piston bore **66** in component **58**. Of course, an additional fixed seal such as **68** and **70** through which a respective rod piston reciprocates would need to be added to each piston as well as an exterior connection for a control line into the chamber **56** to make the system double acting.

[0008] Thus the problem solved by the present invention is presented. How can a rod piston design be double acting without requiring another housing connection for an annular chamber that communicates to all the rod piston bores on the other side of a piston seal from control line connection **26'** so as to avoid the issue of piston bore alignment described with regard to FIG. 2. The present invention manages to provide access to the same rod piston bores on the opposite side of piston seals internally without needing another housing component so as to make moot the issue of bore alignment. Those skilled in the art will better understand the invention from the description of the preferred embodiment and

the associated drawings while understanding that the full scope of the invention is given by the appended claims. While the preferred embodiment is focused on a downhole isolation valve to illustrate the concept it will be recognized that a wide variety of other tools that are operated with hydraulic control lines can also benefit from the present invention.

SUMMARY OF THE INVENTION

[0009] A downhole tool is hydraulically actuated through a control system that features rod piston(s) that are double acting. The piston bore is in a single housing component with an annular cavity to provide access to all piston bores to move the pistons in a first direction. The housing component that has the piston bore also includes an internal sleeve in a passage in the housing. A second control system connection communicates with a sealed annular space defined between the sleeve and the housing wall that holds the sleeve. A series of radial ports communicate from the annular space into each piston bore on the opposite side of each piston seal from the annular cavity so that each piston is double acting with a bore in a single housing component.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 illustrates a control system using opposed single acting pistons that can turn a ball between an open and a closed position;

[0011] FIG. 2 illustrates the problem with making rod pistons double acting by illustrating that a second annular cavity requires a second housing joint so that a single piston bore is in adjacent housing joints making piston bore alignment very difficult;

[0012] FIG. 3 is a close up view showing how the rod pistons are made double acting with a piston bore in a single housing component to avoid the alignment issues shown in FIG. 2;

[0013] FIG. 4 is the view of FIG. 3 showing how the control system is integrated with a downhole isolation valve as one possible application;

[0014] FIG. 5 is the view of FIG. 1 showing more details of the downhole isolation valve equipped with opposed single acting pistons; and

[0015] FIG. 6 is what a downhole isolation valve of FIG. 5 would look like with the double acting rod pistons and is used to show the length decrease in the tool made possible from use of the double acting rod pistons.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] FIG. 3 shows one of several pistons **70** each disposed in a discrete bore **72** where the entirety of the bore **72** extends in a single housing piece **74**. An upper housing component **76** is connected to component **74** at interior two step seal **78** and **80** and at exterior two step thread **82** and **84**. In between lies an annular chamber **86** that communicates to the top of all the rod piston bores **72**. Pressure applied through hydraulic connection **88** to which is connected a control line from the surface (not shown) pushes on pistons **70** at their upper seal **90**. Piston **70** extends through a stationary seal **92** and is connected at end **94** to a slide **96**. As shown in FIG. 6 ball **98** is in a stationary frame **100** and is able to rotate in place about fixed axis **102**. Slide **96** is connected to ball **98** in an offset location from the central pivot axis **102**. The movement of the slide **96** rotates the ball **98** preferably 90 degrees between the closed position shown and the open position. Actuation of the pistons **70** moves the slide **96** in opposed directions to open and close the passage **104**. Frame **100** holds opposed sleeves **106** and **108** fast against the ball **98** to hold the sealing surfaces **110** and **112** against the ball **98**. Seals **114** and **116** seal the exterior of sleeves **106** and **108** respectively so that with ball **98** in the FIG. 6 position, there is no leakage past ball **98**.

[0017] Referring back to FIG. 3, housing component **76** has a second control line connection **118** to which another control line from the surface (not shown) is connected. Connection **118** leads to a radial passage **120** that communicates with an annular space **122** between the sleeve **106** and the inner wall **124** of housing components **74** and **76**. The annular space **122** is defined between seal **126** barely seen in FIG. 3 but better seen in FIG. 6 at the upper end and seal **114** at the lower end**.** In between seals **114** and **126** there are radial passages leading from the annular space **122** to each piston bore **72** but on the opposite side of piston seal **90** than hydraulic fluid from connection **88**.

[0018] Those skilled in the art will now clearly see that the rod piston bores **72** are in a single housing component **74** to remove the alignment issues discussed in connection with FIG. 2. Each rod piston **70** is double acting within the confines of a single housing component **74**. What makes all this possible is the use of an annular internal passage **122** around sleeve **106** that provides access to each of the piston bores **72** on the back side of the piston **70** provided by a series

of radial holes **128** leading into the piston bore **72** on the opposite side of the piston seal **90**. As a result, the overall length of a given tool can be substantially shortened as can be seen by comparing FIGS. 5 and 6. In FIG. 6 with all the rod pistons **70** located above the ball **98** the lower sleeve **108** is considerably shorter than its counterpart **108'** in FIG. 5 using opposed single acting pistons **32** and **34** above ball **10** and opposed pistons **40** and **42** below ball **10**. In essence the sleeve **108** in FIG. 6 no longer has to straddle a set of pistons that are no longer there and can as a result be made much shorter. The overall tool length can also be shorter.

[0019] A variety of tools that operate downhole with control lines can benefit from double acting rod pistons while reducing the overall length. Such tools can include subsurface valves, sliding sleeves, ported sub or any other tool where opposed movement is used for its operating positions. In essence, the present invention allows for the creation of an internal annular space adjacent to a housing component that has a rod piston and takes advantage of that annular space to get access to all rod piston bores by simply providing radially drilled passages into the piston bores on a side opposite of a piston seal and in the same piston bore. A simple solution allows the piston bore to be in a single housing component and still permit a double acting capability to shorten overall tool length.

[0020] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below.

We claim:

1. A control system for a subterranean tool, comprising:

a multi-component housing having a movable member therein;

at least one hydraulically actuated double acting rod piston in a piston bore in said housing and connected to said movable member;

said piston bore fully disposed in a single component of said housing.

2. The system of claim **1**, wherein:

said piston comprises a seal that divides said piston bore into a first and a second variable volume components;

access into one of said volume components is through said single component of said housing.

3. The system of claim **2**, wherein:

said housing comprises a passage therein with a sleeve disposed therein to define an annular space therebetween;

said annular space leading to a passage through said single component and into one of said variable volume components of said piston bore.

4. The system of claim **3**, wherein:

said housing comprises a first hydraulic connection leading to an annular space in a wall of said housing and communicating with said first variable volume component of said piston bore.

5. The system of claim **4**, wherein:

said housing comprises a second hydraulic connection leading to said annular space defined by said sleeve and to said second variable volume component of said piston bore.

6. The system of claim **5**, wherein:

said single housing component contains a radial passage connecting said annular space to said second variable volume component of said piston bore.

7. The system of claim **6**, wherein:

said annular space comprises opposed end seals to communicate pressure applied to said second hydraulic connection through said annular space and said radial passage and into said second variable volume component of said piston bore.

8. The system of claim **1**, wherein:

said movable member is a slide that operates a ball between an open and a closed position in a passage in said housing.

9. The system of claim **1**, wherein:

said at least one hydraulically actuated double acting piston comprises a plurality of pistons each in its own bore where all said piston bores are in a wall of a single component of said housing.

10. The system of claim **9**, wherein:

all said piston bores are in fluid communication on a first side of the respective pistons in said bores through a first connection on the exterior of said housing;

all said piston bores are in fluid communication on a second side of the respective pistons in said bores through a second connection on the exterior of said housing.

11. The system of claim **10**, wherein:

said first and second connections are in an adjacent housing component to said single component that houses said piston bores.

12. The system of claim **11**, wherein:

said first connection in communication with an annular chamber defined between said single and adjacent housing components that is also in fluid communication with a first side of all said pistons in said piston bores.

13. The system of claim **12**, wherein:

said second connection communicating with a sealed passage in said housing that leads to said second side of all said pistons in said piston bores.

14. The system of claim **13**, wherein:

said sealed passage is an annular passage defined between a sleeve in a bore in said single and adjacent housing components.

15. The system of claim **14**, wherein:

said single housing component comprises a bore from said sealed passage to each of said second sides of said pistons in said piston bores.

16. The system of claim **9**, wherein:

all said piston bores are disposed parallel to each other in the wall of said single housing component.