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Bosch

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[54] **RADIAL PISTON MACHINE**

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[51] **Int. Cl.** **F01b 13/06**

[58] **Field of Search** 91/487, 485, 6.5, 507

[56] **References Cited**

UNITED STATES PATENTS

2,944,529	7/1960	Wiggermann	91/6.5
3,082,696	3/1963	Henrichsen	91/487
3,171,361	3/1965	Boulet	91/487
3,199,461	8/1965	Wolf	91/6.5
3,369,458	2/1968	Slimm	91/507
3,520,229	7/1970	Slimm et al.	91/6.5

FOREIGN PATENTS OR APPLICATIONS

1,239,955	7/1971	United Kingdom	91/498

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[57] **ABSTRACT**

A radial piston machine wherein the cylinder block rotates about a stationary pintle having in its external surface a high-pressure chamber and a low-pressure chamber, and wherein the cylinder block has radially outwardly extending cylinder bores travelling seriatim in register with the chambers and with lands provided on the pintle between the two chambers. The lands of the pintle are provided with recesses in the form of cutouts or cavities which are in temporary communication with successive cylinder bores when the cylinder block rotates so that the pressure fields which develop in the region of the recesses communicating with cylinder bores containing pressurized fluid oppose radial movements of the cylinder block. The recesses in the lands of the pintle can be replaced by or provided in addition to recesses in the internal surface of the cylinder block.

14 Claims, 6 Drawing Figures

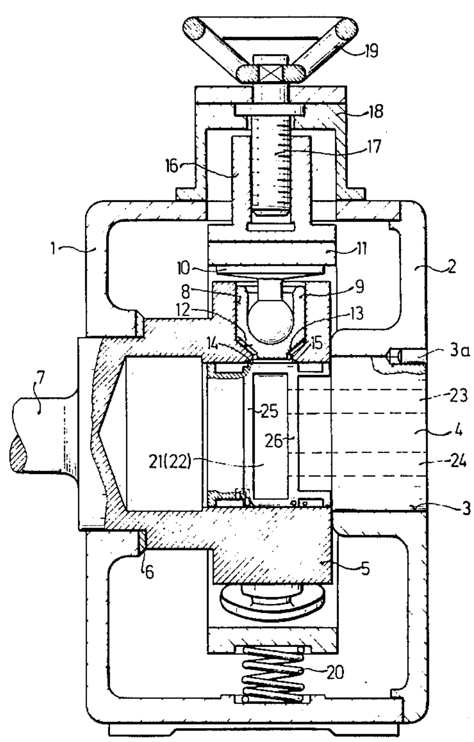


Fig.1

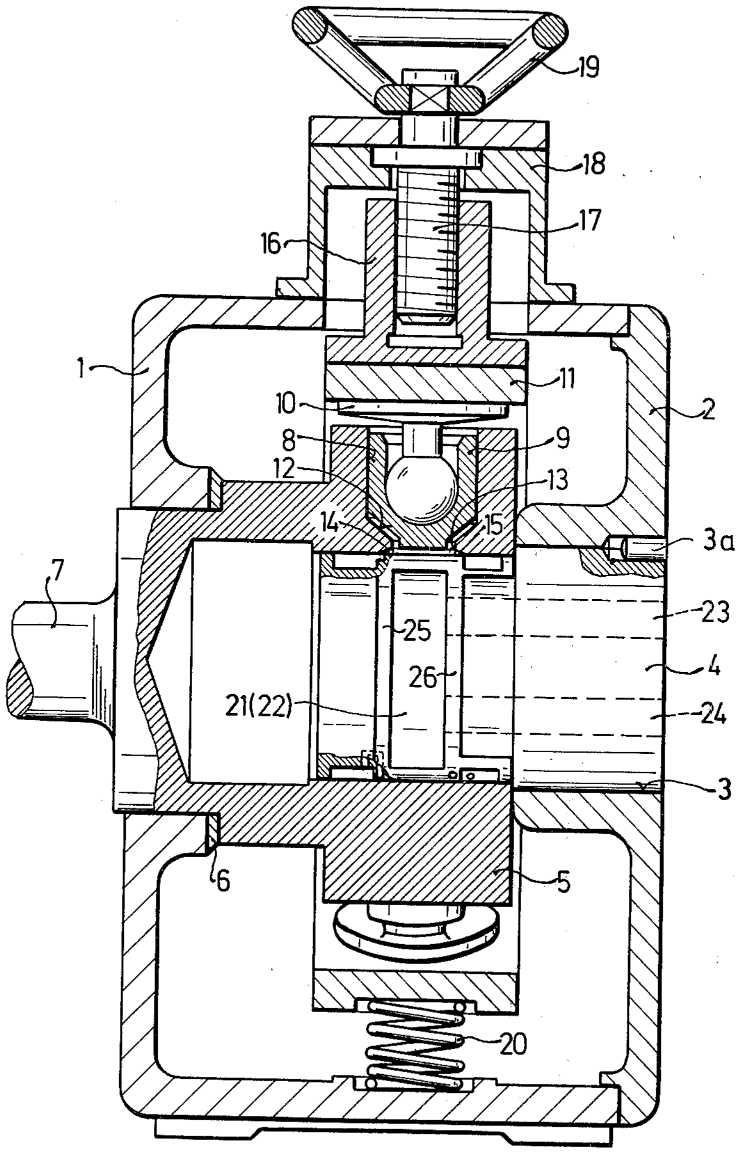


Fig. 2

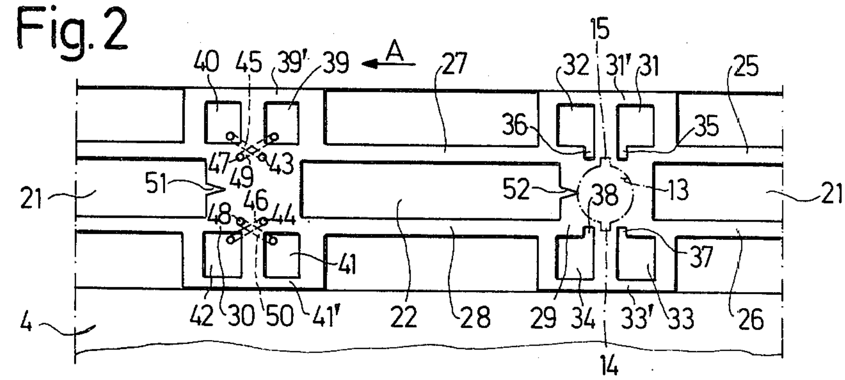


Fig. 3

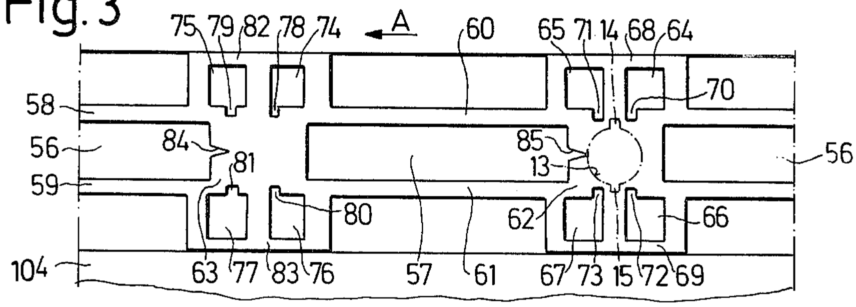


Fig. 4

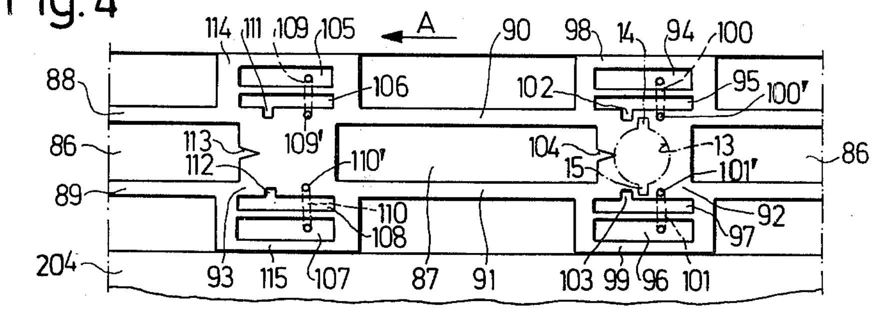


Fig. 5a

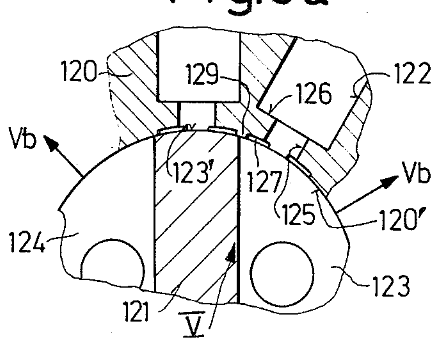
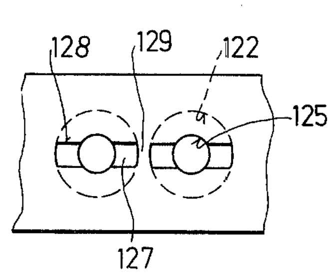


Fig. 5b



RADIAL PISTON MACHINE

BACKGROUND OF THE INVENTION

The present invention relates to radial piston machines, and more particularly to improvements in radial piston machines of the type wherein a cylinder block having radially extending cylinder bores rotates about a stationary valve or pintle whose periphery is provided with a high-pressure chamber and a low-pressure chamber.

It is already known to provide a radial piston machine with a pintle having in its external surface two arcuate chambers separated from each other by lands. The inner end portions of the cylinder bores orbit along a path which is adjacent to the chambers and to the lands so that each cylinder bore communicates first with one of the chambers, thereupon travels along one of the lands, then communicates with the other chamber, thereupon travels along the other land, and again communicates with the one chamber. A drawback of presently known radial piston machines of the just outlined character is that the forces which develop when a piston moves in the cylinder block radially inwardly, i.e., toward the inner end portion of the respective cylinder bore, tend to flex the pintle away from the respective inner end portion and simultaneously tend to move the adjacent portion of the cylinder block radially of and away from the pintle. At the same time, the portion of the cylinder block which is located opposite the piston dwelling in its inner end position tends to move nearer to the adjacent portion of the external surface on the pintle. While the liquid which fills the clearance between the internal surface of the cylinder block and the external surface of the pintle opposes such radial displacements of the cylinder block, its resistance is not always sufficient to insure accurate centering of the cylinder block so that pressurized liquid is likely to leak in the region where a piston assumes its inner end position and the losses due to friction between the cylinder block and the pintle opposite such region are extremely high.

It is further known to reduce the effect of forces which tend to move the cylinder block radially of the pintle by providing the lands between the high-pressure and low-pressure chambers of the pintle with recesses in the form of cutouts or cavities. The pintle contains a system of valve elements serving to connect the higher-pressure chamber with the recess or recesses which are located opposite a piston in its inner end position. This results in the establishment of high-pressure fields which are capable of counteracting some but not all of the forces tending to move the cylinder block radially of the pintle. In addition to unsatisfactory neutralization of radial forces, the just described radial piston machine exhibits the serious drawback that the valve elements in the pintle contribute excessively to the initial and maintenance cost of the machine. The maintenance cost is high because the channels wherein the pressurized fluid flows between the high-pressure chamber and selected recesses are likely to be clogged by impurities in the fluid to thereby reduce the effectiveness of the centering action upon the cylinder block and to cause excessive wear upon the neighboring surfaces of the cylinder block and pintle.

SUMMARY OF THE INVENTION

An object of the invention is to provide a novel and improved radial piston machine wherein the forces tending to move the cylinder block radially of the pintle are balanced or neutralized with greater accuracy and with a higher degree of reliability than in presently known machines.

Another object of the invention is to provide a novel and improved pintle and a novel and improved cylinder block for use in radial piston machines of the just outlined character.

A further object of the invention is to provide a radial piston machine whose pintle and cylinder block are simpler than in the aforementioned radial piston machines wherein the pintle is provided with valve elements, and wherein the balancing of radial forces acting on the cylinder block is achieved in a simpler, less expensive and more reliable way than in heretofore known machines.

An additional object of the invention is to provide a radial piston machine wherein the radial forces acting on the cylinder block are neutralized to such an extent that the combined area of surfaces provided on the pintle and serving to guide the cylinder block can be reduced sufficiently to greatly reduce losses due to friction when the cylinder block is caused to rotate relative to the pintle.

Still another object of the invention is to provide a radial piston machine which can stand longer periods of use than heretofore known machines because the wear upon the neighboring surfaces of the cylinder block and pintle is a small fraction of such wear in conventional machines, and wherein the leakage of fluid between the cylinder block and the pintle is a small fraction of leakage in presently known machines.

One feature of the invention resides in the provision of a radial piston machine which can be used as a pump or as a motor and comprises a rotary cylinder block having a cylindrical internal surface and radially extending equidistant cylinder bores including end portions (e.g., in the form of round ports) terminating in the internal surface of the block, and a stationary valve or pintle having a cylindrical external surface surrounded by the internal surface of the cylinder block, a high-pressure chamber and a low-pressure chamber machined into the external surface in such positions as to register with and to be swept seriatim by the end portions of successive cylinder bores when the cylinder block rotates relative to the valve. The external surface of the valve includes two portions which constitute lands between the two chamber, and the lands are provided with recesses in the form of cutouts or cavities which are offset relative to the chambers, as considered in the axial direction of the cylinder block. Each recess is in temporary communication with that cylinder bore whose end portion travels in the region of the respective land whereby the pressure fields which develop in the recesses communicating with the high-pressure chamber (by way of the end portions of the cylinder bores) are capable of at least partially counteracting the radial forces which tend to move the cylinder block toward or away from the valve.

The aforementioned recesses are more effective than the valve elements in the pintles of conventional radial piston machines but their machining into the external surface of the valve can be carried out at a fraction of the cost of such valve elements.

Another feature of the invention resides in the provision of recesses in the form of cavities or cutouts which are machined into the internal surface of the cylinder block to perform substantially the same function as the recesses in the lands of the valve. The recesses in the cylinder block can be provided in addition to or as a substitute for recesses in the lands of the valve.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved radial piston machine itself, however, both as of its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a somewhat schematic vertical sectional view of a radial piston machine having a cylinder block and a valve embodying one form of the invention;

FIG. 2 is a developed view of the valve in the radial piston machine of FIG. 1;

FIG. 3 is a developed view of a modified valve;

FIG. 4 is a developed view of a third valve;

FIG. 5*a* is a fragmentary transverse sectional view of a radial piston machine embodying a modified cylinder block; and

FIG. 5*b* is a developed view of the internal surface of the cylinder block substantially as seen in the direction of arrow V in FIG. 5*a*.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIGS. 1 and 2, there is shown a radial piston machine which comprises a housing **1** provided with a separable cover or lid **2**. The cover **2** is formed with a bore **3** for a cylindrical valve or pintle **4** which is secured to the cover by means of a pin **3***a*. The pintle **4** is surrounded by a cylinder body or block **5** which is rigid (e.g., integral) with a shaft **7**. The shaft **7** is driven by the block **5** when the machine is operated as a motor, and the shaft **7** drives the block **5** when the machine is operated as a pump. A shoulder of the block **5** abuts against a bearing **6** mounted in the housing **1** and surrounding the shaft **7**.

The block **5** is provided with radially extending cylinder bores **8** for pistons or plungers **9** each of which has a shoe **10** abutting against the cylindrical internal surface of a floating control ring **11** which surrounds the block **5**. The pistons **9** are reciprocable in the respective cylinder bores **8** with minimal clearance. The inner part of each cylinder bore **8** is surrounded by a conical surface **12** and terminates in a circular end portion or port **13** as well as in two grooves **14, 15** which are disposed diametrically opposite each other with reference to the center of the respective port **13** and are located in a plane which includes the common axis of the cylinder block **5** and pintle **4**.

The means for changing the position of the control ring **11** radially of the block **5** and for thereby changing the strokes of the pistons **9** comprises a nut **16** which is secured to and extends radially outwardly of the control ring **11**, a spindle **17** which meshes with the nut **16** and is rotatable in a bell **18** of the housing **1**, and a hand wheel **19** which is secured to the outer end portion of the spindle **17**. The latter is held against axial movement so that, when the hand wheel **19** is rotated, the nut **16** moves the control ring **11** radially of the cylinder block **5** and thereby changes the strokes of the pistons **9**. A helical spring **20** reacts against the housing **1** and biases the control ring **11** upwardly, as viewed in FIG. **1**, i.e., in the axial direction of the spindle **17**.

The pintle **4** is formed with two axially parallel holes **23, 24** one of which terminates in an inlet and the other of which terminates in an outlet for a fluid medium, e.g., oil. The inner end portions of the holes **23, 24** respectively communicate with arcuate control chambers **21, 22** which are machined into the cylindrical external surface of the pintle **4** and register with the cylinder bores **8**. Thus, when the cylinder block **5** rotates about the pintle **4**, successive ports **13** sweep past the control chambers **21, 22** so that the pistons **9** can draw fluid into the respective cylinder bores **8** while moving radially outwardly and that the pistons can expel fluid from the respective bores **8** during movement toward the axis of the pintle **4**. The control chambers **21, 22** are of identical length, as considered in the circumferential direction of the pintle **4**, and are separated from each other by two axially parallel lands **29, 30** best shown in FIG. **2**. Each of the lands **29, 30** constitutes a portion of the cylindrical external surface of the pintle **4**. The control chamber **21** is flanked by two narrow sealing ribs **25, 26** which extend in the circumferential direction of the pintle **4** between the lands **29, 30**, and the control chamber **22** is flanked by two similar sealing ribs **27, 28**. The width of the control chamber **21** and sealing ribs **25, 26** respectively equals or approximates that of the control chamber **22** and sealing ribs **27, 28**.

In accordance with a feature of the invention, the land **29** between the control chambers **21, 22** is provided with four substantially rectangular recesses in the form of cutouts or cavities **31, 32, 33** and **34** which are respectively provided with narrow and short channels or extensions **35, 36, 37, 38**. The extensions **37, 38** are adjacent to the path of successive grooves **14** and the extensions **35, 36** are adjacent to the path of successive grooves **15**. The arrow A denotes in FIG. **2** the direction in which the cylinder block **5** rotates relative to the periphery of the pintle **4**. The cutouts **31, 32** are outwardly adjacent to the sealing ribs **25, 27** and the cutouts **33, 34** are outwardly adjacent to the sealing ribs **26, 28**. The arrangement is such that successive ports **13** and the corresponding grooves **14, 15** can establish communication between the control chamber **21** and cutouts **31, 33** and thereupon between the control chamber **22** and cutouts **32, 34**. The pintle **4** is further provided with a first auxiliary sealing rib **31'** which is outwardly adjacent to the cutouts **31, 32** and merges into the land **29**, and with a second auxiliary sealing rib **33'** which is outwardly adjacent to the cutouts **33, 34** and also merges into the land **29**. The length of each of the extensions **35–38**, as considered in the axial direction of the pintle **4** (i.e., vertically, as viewed in FIG. **2**), may but need not equal the corresponding dimension of the groove **14** or **15**.

The land **30** between the control chambers **22, 21** is also provided with four recesses in the form of cutouts or cavities **39, 40, 41, 42** which respectively communicate with channels in the form of small bores **49, 45,** 50, 46. The cutouts **39, 40** are outwardly adjacent to the sealing ribs **25, 27** and the cutouts **41, 42** are outwardly adjacent to the sealing ribs **26, 28** (as considered in the axial direction of the pintle **4**). The cutouts **40** and **42** are respectively located behind the cutouts **39, 41,** as considered in the direction of rotation of the cylinder block 5 (arrow A). The bores 46, 50 are respectively provided with inlets 44, 48 which are adjacent to the path of movement of successive grooves 14, and the bores 45, 49 respectively have inlets 43, 47 which are adjacent to the path of movement of successive grooves 15. An auxiliary sealing rib 39' of the pintle 4 is outwardly adjacent to the cutouts 39, 40, and a similar auxiliary sealing rib 41' is outwardly adjacent to the cutouts 41, 42. The auxiliary sealing ribs 39', 41' merge into the land 30. The bores 45, 46 can cooperate with successive ports 13 and the associated grooves 14, 15 to establish communication between the control chamber 22 and the cutouts 40, 42. The bores 49, 50 can cooperate with successive ports 13 and the associated grooves 14, 15 to establish communication between the control chamber 21 and the cutouts 39, 41. Thus, successive grooves 14 and the corresponding ports 13 will connect first the chamber 22 with the cutout 42 and thereupon the chamber 21 with the cutout 41, and successive grooves 15 and the associated ports 13 will connect the chamber 22 first with the cutout 40 and thereupon the chamber 21 with the cutout 39.

The control chamber 21 communicates with a tapering triangular pilot notch 51 which extends into the land 30 and insures a gradually increasing communication between successive ports 13 and the chamber 21 when the cylinder block 5 rotates. The control chamber 22 communicates with a similar tapering triangular pilot notch 52 which extends into the land 29 and insures a gradually increasing communication between successive ports 13 and the chamber 22. The length of the pilot notch 51 (as considered in the circumferential direction of the pintle 4) is selected in such a way that a port 13 begins to communicate with the control chamber 21 only after the corresponding grooves 14, 15 have moved beyond the inlets 44, 43 of the bores 46, 45. Analogous, the length of the pilot notch 52 is such that a port 13 begins to communicate with the control chamber 22 only after the respective grooves 14, 15 have advanced beyond the extensions 37, 35 of the cutouts 33, 31. As shown in FIG. 2, the grooves 14, 15 are positioned in such a way that the groove 14 respectively communicates with the extensions 37, 38 when the associated groove 15 registers with the extensions 35, 36, and that the groove 14 respectively registers with the inlets 44, 48 when the groove 15 respectively registers with the inlets 43, 47.

The operation:

When the cylinder block 5 rotates in the direction indicated by arrow A, the end portions or ports 13 of successive cylinder bores 8 orbit about the axis of the pintle 4 and sweep seriatim along the control chamber 21, land 29, control chamber 22, land 30, control chamber 21, etc. By following the orbital movement of a single port 13 and the associated grooves 14, 15, it will be seen that, when the port 13 reaches the land 29, the grooves 14, 15 respectively move into register with the extensions 37, 35 before the port 13 moves beyond the control chamber 21, i.e., the port 13 and the associated grooves 14, 15 establish communication between the control chamber 21 and the cutouts 31, 33. The communication between the control chamber 21 and cutouts 31, 33 is of short duration but suffices to insure an equalization of pressure of fluid in the chamber 21 and cutouts 31, 33. If the control 21 is connected to the suction (low-pressure) opening of the pintle 4, the pressure in the cutouts 31, 33 increases negligibly so that pressure fields developing in the region of these cutouts do not contribute significantly to balancing of forces which tend to move the cylinder block 5 radially of the pintle 4.

As the cylinder block 5 continues to rotate, the port 13 and the associated grooves 14, 15 respectively move out of register with the control chamber 21 and cutouts 33, 31. At such time, the corresponding piston 9 changes the direction of its movement in the respective cylinder bore 8. The port 13 then reaches the pilot notch 52 and thus begins to communicate with the control chamber 22 which contains pressurized fluid. Thus, there begins to take place an equalization of pressures between the interior of the chamber 22 and the adjacent bore 8. Shortly thereafter, the grooves 14, 15 respectively reach the extensions 38, 36 so that the cutouts 34, 32 receive pressurized fluid and the pressure therein rises to a maximum value at the time when the port 13 is in full or substantial register with the control chamber 22 but the grooves 14, 15 continue to communicate with the extensions 38, 36. When the grooves 14, 15 respectively advance beyond the extensions 38, 36, the pressure of fluid in the cutouts 34, 32 gradually decreases due to leakage of fluid between the periphery of the pintle 4 and the cylinder block 5. The pressure of fluid in the cutouts 34, 32 rises again when the next groove 15 begins to communicate first with the pilot notch 52 and thereupon directly with the control chamber 22.

When the port 13 begins to advance beyond the control chamber 22, the grooves 14, 15 respectively communicate with the inlets 44, 43 of the bores 46, 45 before the communication between the control chamber 22 and port 13 is interrupted. There takes place an equalization of pressures between the control chamber 22 and the cutouts 42, 40 which respectively communicate with the bores 46, 45. The pressure in the cutouts 42, 40 begins to decrease as soon as the grooves 14, 15 respectively advance beyond the inlets 44, 43, i.e., as soon as the port 13 is sealed from the bores 46, 45. The same procedure is repeated when the next port 13 begins to advance beyond the control chamber 22 so that the grooves 14, 15 which are associated with the next port 13 move past the inlets 44, 43.

The port 13 moves along the land 30 when the corresponding piston 9 reaches the inner end of its stroke. The pressurized fluid in the cutouts 42, 40 then balances the force which tends to urge the cylinder block 5 against the pintle 4 whenever a piston 9 reaches the inner end of its stroke. The drop of fluid pressure in the cutouts 42, 40 is slower than in the cutouts 34, 32 which are disposed diametrically opposite the cutouts 42, 40 with reference to the axis of the pintle 4. This is due to the fact that the clearance between the cylinder block 5 and the pintle 4 in the region of the cutouts 42, 40 is smaller than in the region of the cutouts 34, 32. Consequently, the fluid in the cutouts 42, 40 can, on the average, offer a greater resistance to radial displacement of the cylinder block 5 than the fluid in the cutouts 34, 32. The widths of the gaps between the cylinder block 5 and pintle 4 automatically assume such values that the forces acting on the pintle 4 balance or neutralize each other.

When the port 13 advances beyond the control chamber 22, it moves into register with the pilot notch 51 of the control chamber 21. In the meantime, the corresponding piston 9 has changed the direction of its movement so that it travels radially outwardly to draw fluid into the respective bore **8**. The pressure in the bore **8** begins to approach that in the control chamber **21** and the cutouts **41, 39** begin to receive fluid from the control chamber **21** by way of the port **13**, grooves **14, 15**, inlets **48, 47** and bores **50, 49**. The pressure fields in the region of the cutouts **41, 39** correspond to those in the region of the cutouts **33, 31**, i.e., they are relatively weak and do not offer a substantial resistance to radial displacement of the cylinder block **5**. When the grooves **14, 15** advance beyond the inlets **48, 47**, the cylinder block **5** has completed one full revolution.

It will be noted that the pressure fields in the region of the cutouts at one end of the control chamber **21** or **22** develop subsequent to development of such pressure fields in the region of cutouts at the other end of the respective control chamber. In spite of continuous fluctuations of fluid pressure in the cutouts, the arrangement of FIG. **2** insures a highly satisfactory neutralization of forces which act upon the pintle **4** and further insures that the pressure fields in the region of cutouts are capable of withstanding the tendency of the cylinder block **5** to move radially of the pintle. Due to the aforedescribed symmetric distribution of cutouts with reference to the axis of the pintle **4**, the machine operates satisfactorily irrespective of the direction of rotation of the cylinder block **5** and irrespective of whether the control chamber **21** or **22** contains pressurized fluid.

Another advantage of the structure shown in FIG. **2** is that the pressure fields in the region of cutouts can stand substantial radial forces which tend to move the cylinder block **5** relative to the pintle **4** and which tend to flex the pintle so that the combined area of the sealing ribs **25–28**, lands **29, 30** and auxiliary sealing ribs **31', 33', 39', 41'** can be made small. This reduces the losses due to friction.

The cutouts or recesses **31–34** and **39–42** form two groups of cutouts one of which is provided in the land **29** and the other of which is provided in the land **30**. Each group comprises two cutouts (**31, 33** and **40, 42**) which can communicate with successive cylinder bores **8** before such bores communicate with the other two cutouts (**32, 34** and **39, 41**). All of the cutouts are offset relative to the control chambers **21, 22**, as considered in the axial direction of the pintle **4**.

FIG. **3** illustrates the cylindrical external surface of a modified valve or pintle **104**. The control chambers are shown at **56** and **57**, the narrow sealing ribs for the chambers **56** and **57** at **58, 59** and **60, 61**, and the lands at **62** and **63**. The land **62** is provided (as considered in the direction of arrow A) with recesses or cutouts **64, 65** having channels or extensions **70, 71** located in the path of movement of successive grooves **14**, and with recess or cutouts **66, 67** having channels or extensions **72, 73** located in the path of movement of successive grooves **15**. The cutouts **64, 66** can communicate with the control chamber **56** and the cutouts **65, 67** can communicate with the control chamber **57**. The auxiliary sealing ribs for the cutouts **64, 65** and **66, 67** are respectively shown at **68** and **69**. The length of the extensions **70, 71** and **72, 73**, as considered in the circumferential direction of the pintle **104**, is selected in such a way that they can register fully or to a substantial extent with the grooves **14** and **15**.

The land **63** of the pintle **104** is provided with recesses or cutouts **74, 76** which can communicate with the control chamber **57** by way of their channels or extensions **78, 80**, successive grooves **14, 15** and the corresponding ports **13**. The land **63** is further provided with recesses or cutouts **75, 77** having channels or extensions **79, 81** which can communicate with the control chamber **56** by way of successive grooves **14, 15** and the associated ports **13**. The pilot notches of the chambers **56, 57** are respectively shown at **84** and **85**. The auxiliary sealing ribs for the cutouts **74, 75** and **76, 77** are respectively shown at **82** and **83**. The extensions **70, 71, 78, 79** and **72, 73, 80, 81** begin to communicate with the respective grooves **14, 15** when the corresponding ports **13** are still in some communication or begin to communicate with the respective control chamber **56, 57**. Thus, the length of intervals during which the cutouts communicate with the respective control chambers is relatively short.

It will be noted that the pilot notches **84, 85** taper counter to the direction (arrow A) of rotation of the cylinder block (not shown in FIG. **3**). The length of pilot notches **84, 85** is selected in such a way that, when a port **13** travels for example toward the control chamber **57** (see the position of the port **13** in FIG. **3**), the corresponding grooves **14, 15** move beyond the extensions **70, 72** before the port **13** reaches the tip of the pilot notch **85**. The same applies for the extensions **78, 80** and the pilot notch **84**.

The distance between the extensions **71, 78** or the extensions **73, 80** which can be communicatively connected to the chamber **57** is a whole multiple of the distance between the centers of two neighboring ports **13** in the cylinder block, as considered in the circumferential direction of the pintle **104**. The same applies for the extensions **79, 70** or **81, 72** which can communicate with the control chamber **56**. The remainder of the hydraulic machine which embodies the pintle **104** of FIG. **3** is assumed to be identical with that of the machine shown in FIG. **1**.

The sequence in which the pressure fields develop in the region of cutouts **64–67** and **74–77** is analogous to that for the pressure fields in the region of cutouts shown in FIG. **2**. In contrast to the operation of the embodiment of FIGS. **1–2**, the equalization of pressure in all cutouts which are associated with the control chamber **56** or **57** takes place simultaneously. The pressure fields which develop in the region of the cutouts **65, 74** resp. **67, 76** which can be connected to the control chamber **57** are spaced apart a distance which is less than 180°, as considered in the circumferential direction of the pintle **104**. Therefore, such pressure fields have components which are added to each other and act in directions normal to a symmetry plane extending midway across the lands **62** and **63**. These components balance the forces which tend to urge the cylinder block toward the pintle **104** in the region of the high-pressure control chamber.

The force which tends to move the cylinder block toward the pintle **104** at the inner dead center position of a piston is balanced by the corresponding component of the pressure field in the region of that cutout which is located opposite such piston. That component of the last mentioned pressure field which acts in the same direction as the force acting to move the cylinder block toward the pintle **104** in the region of a piston dwelling in its innermost position is automatically reduced (prior to being fully neutralized) due to the fact that the gap in the region of the respective cutout increases with the result that the pressure field becomes weaker until the forces acting on the cylinder block balance each other. This also neutralizes the forces acting on the pintle 104 because the latter takes up radial stresses acting on the cylinder block.

As a rule, pressure fields develop only in the region of those cutouts which communicate with the high-pressure control chamber of the pintle, i.e., only such pressure fields exert a pronounced influence on the balance of forces acting on the cylinder block. The pressure fields which develop in the region of the cutouts in communication with the low-pressure (suction) chamber are normally negligible. However, if the direction of rotation of the cylinder block remains unchanged while the direction of fluid flow changes the low-pressure chamber becomes the high-pressure chamber and vice versa. Due to aforedescribed symmetric distribution of cutouts in the periphery of the pintle 4 or 104, the forces acting on the cylinder block are balanced again whereby the previously negligible pressure fields contribute significantly to a balancing of forces which act upon the cylinder block, and vice versa.

The combined area of relatively small sealing ribs 58–61, lands 62, 63 and auxiliary sealing ribs 68, 69, 82, 83 suffices for satisfactory guidance of the cylinder block and counteracts the unbalanced hydrostatic forces. At the same time, the losses due to friction are minimal.

FIG. 4 shows a further valve or pintle 204 having two elongated control chambers 86, 87, two lands 92, 93, and sealing ribs 88, 89 and 90, 91 which respectively flank the control chambers 86, 87. The land 92 has four rectangular recesses or cutouts 94, 95, 96 and 97 of different sizes. The smaller cutouts 95, 97 can communicate with the control chamber 87 by way of successive ports 13 and associated grooves 14, 15, and the larger cutouts 94, 96 can communicate in the same way with the control chamber 86. The larger outer cutouts 94, 96 are respectively flanked by auxiliary sealing ribs 98, 99. The cutouts 94, 96 respectively communicate with channels or bores 100, 101 having inlets 100′, 101′ which are respectively adjacent to the path of successive grooves 14, 15. The channels 95, 97 respectively include channels or extensions 102, 103 located in the path of movement of successive grooves 14, 15.

When a port 13 travels along the land 92 from the control chamber 86 toward the control chamber 87, the associated grooves 14, 15 respectively communicate with the inlets 100′, 101′ so that the control chamber 86 is in communication with the cutouts 94, 96 by way of the respective bores 100, 101. The port 13 thereupon begins to communicate with a pilot notch 104 of the control chamber 87 shortly before the grooves 14, 15 reach the extensions 102, 103 of the cutouts 95, 97. The port 13 begins to communicate with the pilot notch 104 after the grooves 14, 15 move beyond the inlets 100′, 101′. The grooves 14, 15 communicate with the extensions 102, 103 while the corresponding port 13 communicates with the control chamber 87.

The land 93 is identical with the land 92. It is provided with two smaller recesses or cutouts 106, 108 having channels or extensions 111, 112 and with two larger recesses or cutouts 105, 107 communicating with channels or bores 109, 110 having inlets 109′, 110′. Successive grooves 14 communicate first with the inlet 109′ to thereby connect the control chamber 87 with the cutout 105, and thereupon with the extension 111 to thereby connect the control chamber 86 with the cutout 106. Analogously, successive grooves 15 communicate first with the inlet 110′ to connect the control chamber 87 with the cutout 107, and thereupon with the extension 112 to connect the control chamber 86 with the cutout 108. The pilot notch 113 of the control chamber 86 begins to communicate with a port 13 after the respective grooves 14, 15 advance beyond the inlets 109′, 110′, and the port 13 communicates with the control chamber 86 while the respective grooves 14, 15 overlie the extensions 111, 112. The larger outer cutouts 105, 107 of the land 93 are flanked by auxiliary sealing ribs 114, 115. It will be noted that the pilot notch 113 extends counter to the direction of rotation (arrow A) of the cylinder block.

The manner in which the pressure fields are built up in a machine embodying the pintle 204 of FIG. 4 is analogous to that described with reference to FIG. 2. If the cylinder block (not shown) rotates in the direction indicated by arrow A, and if the control chamber 87 is the high-pressure chamber, a port 13 travels along the land 93 of the pintle 204 when the corresponding piston is nearest to the axis of the pintle. The pressure fields in the region of the cutouts 105 and 107 develop whenever the grooves 14, 15 associated with a port 13 which is still in communication with the high-pressure chamber 87 reach the inlets 109′, 110′. Such pressure fields are capable of offering a substantial resistance to radial movement of the cylinder block toward the periphery of the pintle 204, and are much more pronounced than the pressure fields in the region of cutouts 95, 97. The cutouts 95, 97 are located diametrically opposite the cutouts 105, 107 and intermittently receive pressurized fluid from the control chamber 87 by way of the pilot notch 104, successive ports 13, associated grooves 14, 15 and the extensions 102, 103. The pressure fields in the region of the cutouts 105, 107 compensate for the force which tends to move the cylinder block toward the land 93 due to the fact that the piston sweeping past the land 93 pressurizes the fluid in the respective cylinder bore. Moreover, the pressure fields in the region of cutouts 105, 107 counteract the pressure fields in the region of cutouts 95, 97. The intensity of such pressure fields is adjusted automatically in that the gap between the pintle 204 and the cylinder block increases wherever the forces are unbalanced whereby the leakage of pressurized fluid increases and the magnitude of the respective pressure fields decreases accordingly. By properly dimensioning the cutouts in the lands 92, 93, one can achieve an extensive balancing of forces and thus an accurate centering of the cylinder block on the pintle.

It will be noted that the larger cutouts 105, 107 in the land 93 communicate with the high-pressure chamber 87 because a piston moves past the land 93 while it pressurizes the fluid in the respective cylinder bore. If the control chamber 86 is the high-pressure chamber, the pistons move radially inwardly during travel toward the land 92 so that pronounced pressure fields develop in the region of the large cutouts 94, 96. Thus, pronounced pressure fields are always established in the region of those larger cutouts which are in communication with successive ports 13 while the respective pistons approach, reach and leave their inner dead-center positions. In this manner, one achieves a highly satisfactory balancing of forces irrespective of the direction of fluid transport, as long as the cylinder block rotates in the same direction. Such balancing of forces renders it possible to greatly reduce the combined area of surfaces (on the sealing ribs and lands) for guidance of the cylinder block which, in turn, results in a substantial reduction of losses due to friction.

The recesses or cutouts **94–97** and **105–108** are located centrally of the lands **92, 93,** as considered in the circumferential direction of the pintle **204.**

FIGS. *5a* and *5b* illustrate a portion of a modified radial piston machine with a presently preferred configuration of cylinder bores in a cylinder block **120** which enhance the balancing of remaining forces acting upon the cylinder block in the region of the high-pressure chamber in the valve or pintle **121.** The cylinder block **120** has an axial bore bounded by an internal surface **120'** which surrounds the pintle **121.** The cylinder bores **122** of the block **120** extend radially outwardly from the internal surface **120'.** The pintle **121** has two control chambers **123, 124** which are separated from each other by lands **123'** (one shown in FIG. *5a*).

Each cylinder bore **122** has an inner end portion or port **125** and the cylinder block **120** has internal shoulders **126** between the main portions of the bores **122** and the respective ports **125.** Each port **125** communicates with a rectangular recess or cavity **127** which is machined into the internal surface **120'** and extends in the circumferential direction of the pintle **121.** The neighboring cavities **127** are separated from each other by narrow webs **129.** The width of a land **123'** on the pintle **121** equals the distance between the centers of two neighboring ports **125,** as considered in the circumferential direction of the pintle. The length of each cavity **127** equals the width of a land **123'** minus the width of a web **129,** as considered in the circumferential direction of the pintle **121.** As a rule, the length of a cavity **127** is between 85% and 95% of the width of a land **123'.** The width of a cavity **127,** as considered in the axial direction of the pintle **121,** is selected in axial direction of the pintle **121,** is selected in such a way that the pressure field developing in the region of such cavity can counteract the remaining force which develops in response to pressurization of fluid in the respective bore **122.**

When a cylinder bore **122** travels from the high-pressure chamber (e.g., control chamber **123**) toward the low-pressure chamber and the respective port **125** moves along the land **123'** of FIG. *5a*, the cavity **127** insures that the bore **122** continues to communicate with the high-pressure chamber. Consequently, the force which the fluid in the bore **122** exerts against the shoulder **126** and which tends to urge the cylinder block **120** against the periphery of the pintle **121** remains intact as long as the adjacent portion of the internal surface **120'** continues to overlie the high-pressure chamber **123.** Such portion of the surface **120'** is subjected to the action of forces V_b which tend to move the cylinder block **120** away from the pintle **121** and which are opposed by fluid pressure acting against the shoulder **126.** In other words, that portion of the cylinder block **120** which extends between the centers of two neighboring ports **125** or between two neighboring webs **129** is acted upon simultaneously by a first force (shoulder **126**) tending to move the cylinder block toward the pintle **121** and by a second force which tends to move the cylinder block away from the pintle. The second force acts upon that portion of the internal surface **120'** (in the region of the respective port **125**) which continues to overlie the high-pressure chamber **123.** Shortly after a cavity **127** moves into full register with the land **123'**, it begins to communicate with the low-pressure chamber **124** so that the force which tends to move the cylinder block **120** away from the pintle **121** decreases simultaneously with the force which tends to move the cylinder block toward the pintle.

When a port **125** moves along the other land of the pintle **121** (on its way from the low-pressure chamber **124** toward the high-pressure chamber **123**), there develops a force which tends to move the cylinder block **120** away from the pintle as soon as the adjacent portion of the internal surface **120'** begins to overlie the chamber **123.** Since the length of a cavity **127** closely approximates the width of a land **123'** (i.e., the distance between the centers of two neighboring ports **125** minus the width of a web **129**), the respective bore **122** begins to communicate with the high-pressure chamber **123** practically simultaneously with the generation of a force which tends to move the cylinder block **120** away from the pintle **121,** whereby the fluid acting on the corresponding shoulder **126** urges the cylinder block toward the pintle and balances the aforementioned separating or lifting force. The two forces act along the same line but in opposite directions so that they can neutralize each other.

Each recess or cavity **127** includes two mirror symmetrical portions **128** (see particularly FIG. *5b*) one of which extends forwardly and the other of which extends rearwardly of the respective port **125,** as considered in the direction of rotation of the cylinder block **120.**

The preceding description indicates that the forces which tend to move the cylinder block toward and away from the pintle neutralize each other in the region of those cylinder bores where the pistons are in the process of changing the direction of their movement. The cavities **1277** evidently do not influence such forces while they are in full register with the high-pressure chamber of the pintle.

The improved pintle and cylinder block are susceptible of many additional modifications without departing from the spirit of the invention. For example, the ports of the cylinder bores can be configurated in such a way that the cavities **127** of FIGS. *5a* and *5b* can be dispensed with. Also, the cutouts in the lands of the pintle need not have a rectangular or square shape, the extensions of the cavities can be replaced by bores, and the bores can be replaced by extensions. The cylinder block **120** of FIGS. *5a* and *5b* can be used in combination with the pintle **4, 104** or **204.**

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of my contribution to the art and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the claims.

What is claimed as new and desired to be protected by letters patent is set forth in the appended:

1. In a radial piston machine, a combination comprising a rotary cylinder block having a cylindrical external surface and radially extending cylinder bores including end portions terminatins in said internal surface; and a valve having a cylindrical external surface surrounded by said internal surface, a high-pressure chamber and a low-pressure chamber provided in said external surface, said chambers being in register with and being swept seriatim by successive end portions when said block rotates relative to said valve and said external surface including two portions constituting lands between said chambers, said external surfaces further having at least two recesses in each of said lands, offset in axial direction of said block relative to said chambers and respectively located to opposite sides of the path of the end portions of successive cylinder bores, each of said recesses being in temporary communication with that cylinder bore whose end portion travels in the region of the respective land.

2. A combination as defined in claim **1**, wherein said internal surface is provided with grooves, at least one for each cylinder bore and each communicating with the respective cylinder bore, said cylinder bores being arranged to communicate with said recesses by way of the respective grooves.

3. A combination as defined in claim **1**, wherein said recesses include a first group of recesses in one of said lands and a second group of recesses in the other of said lands, each group of recesses including at least one first recess which communicates with successive cylinder bores while the end portions of the respective cylinder bores simultaneously communicate with one of said chambers and at least one second recess which communicates with successive cylinder bores while the end portions of the respective cylinder bores communicate with the other of said chambers, said lands further having first and second channels which respectively establish communication between said first and second recesses and successive cylinder bores, the distance between said first channels or said second channels, as considered in the circumferential direction of said valve, being a whole multiple of the distance between the centers of the end portions of two neighboring cylinder bores in said block.

4. A combination as defined in claim **1**, wherein said recesses include a first and a second group respectively provided in the one and the other of said lands and the recesses of each group include at least one first recess which communicates with successive cylinder bores while the end portions of the respective cylinder bores communicate with said high-pressure chamber and at least one second recess which communicates with successive cylinder bores while the end portions of the respective cylinder bores communicate with said low-pressure chamber, the distance between said first recesses, as considered in the circumferential direction of said valve, being less than **180** degrees.

5. A combination as defined in claim **1**, wherein said valve further comprises sealing ribs flanking said chambers and auxiliary sealing ribs flanking said recesses, said sealing ribs constituting with said lands the sole means for guiding said internal surface while said cylinder block rotates relative to said valve.

6. A combination as defined in claim **1**, wherein said recesses include a first and a second group of four recesses each respectively provided in the one and the other of said lands, each of said groups including a first pair of recesses which communicate with successive cylinder bores during the last stage of communication of the corresponding end portions with one of the chambers and a second pair of recesses which communicate with successive cylinder bores during the initial stage of communication of the corresponding ports with the other of said chambers.

7. A combination as defined in claim **6**, wherein one pair of said recesses of each group is located behind the other pair of recesses of the respective group, as considered in the direction of rotation of said cylinder block.

8. A combination as defined in claim **6**, wherein one pair of recesses of each of said groups is nearer to the path of said end portions than the other pair of recesses of the respective group.

9. A combination as defined in claim **1**, wherein said valve is further provided with channels by means of which said recesses communicate with the end portions of successive cylinder bores.

10. A combination as defined in claim **9**, wherein at least some of said channels are bores.

11. A combination as defined in claim **9**, wherein at least some of said channels are extensions of said recesses.

12. A combination as defined in claim **1**, wherein the recesses in each of said lands include at least one first recess and at least one larger second recess, said second recesses being arranged to communicate with those cylinder bores whose end portions simultaneously register with said high-pressure chamber.

13. A combination as defined in claim **12**, wherein said recesses are located substantially centrally of the respective lands, as considered in the circumferential direction of said valve.

14. In a radial piston machine, a combination comprising a rotary cylinder block having a cylindrical internal surface and radially extending cylinder bores including end portions terminating in said internal surface; and a valve having a cylindrical external surface surrounded by said internal surface, a high-pressure chamber and a low-pressure chamber provided in said external surface, said chambers being swept seriatim by successive end portions when said block rotates relative to said valve and said external surface including two portions constituting lands between said chambers, each of said lands being provided with at least one recess adjacent to one side of the path of the end portions of successive cylinder bores, and with at least one second recess adjacent to the other side of said path, said internal surface having a pair of grooves for each of said cylinder bores and the grooves of each pair being in communication with the respective cylinder bores, one groove of each pair being arranged to communicate with said first recesses and the other groove of each pair being arranged to communicate with said second recesses when said cylinder block rotates and said cylinder bores travel in the region of the respective lands.

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