United States Patent [19]
Heyl

[11] **3,906,841**
[45] **Sept. 23, 1975**

[54] **AXIAL-PISTON MACHINE**

[75] Inventor: **Walter Heyl**, Oberafferbach, Germany

[73] Assignee: **Linde Aktiengesellschaft**, Wiesbaden, Germany

[22] Filed: **Aug. 6, 1973**

[21] Appl. No.: **386,012**

[30] **Foreign Application Priority Data**

Aug. 4, 1972 Germany 2238582

[52] **U.S. Cl.** **91/487**
[51] **Int. Cl.**[2] **F01B 1/00**
[58] **Field of Search** 91/487, 488, 499, 506, 91/507

[56] **References Cited**

UNITED STATES PATENTS

3,142,262	7/1964	Firth	91/488
3,292,553	12/1966	Hann	91/507
3,416,312	12/1968	Margolin	91/506
3,522,759	8/1970	Martin	91/507
3,543,649	12/1970	Martin	91/507
3,643,549	2/1972	Nagatomo	91/507

FOREIGN PATENTS OR APPLICATIONS

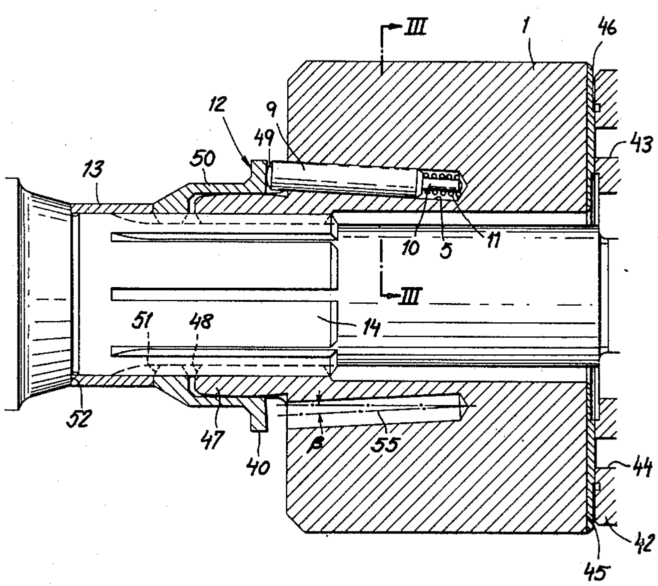
311,938	5/1929	United Kingdom	91/485

Primary Examiner—William L. Freeh
Assistant Examiner—G. P. LaPointe
Attorney, Agent, or Firm—Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

An axial-piston machine having a cylinder drum which is urged under pressure against a surface for distributing fluid thereto, is provided with respective (pressurizing) pistons, each under the pressure of a working cylinder, which react against a common body to develop the force retaining the cylinder drum against the control surface.

3 Claims, 5 Drawing Figures



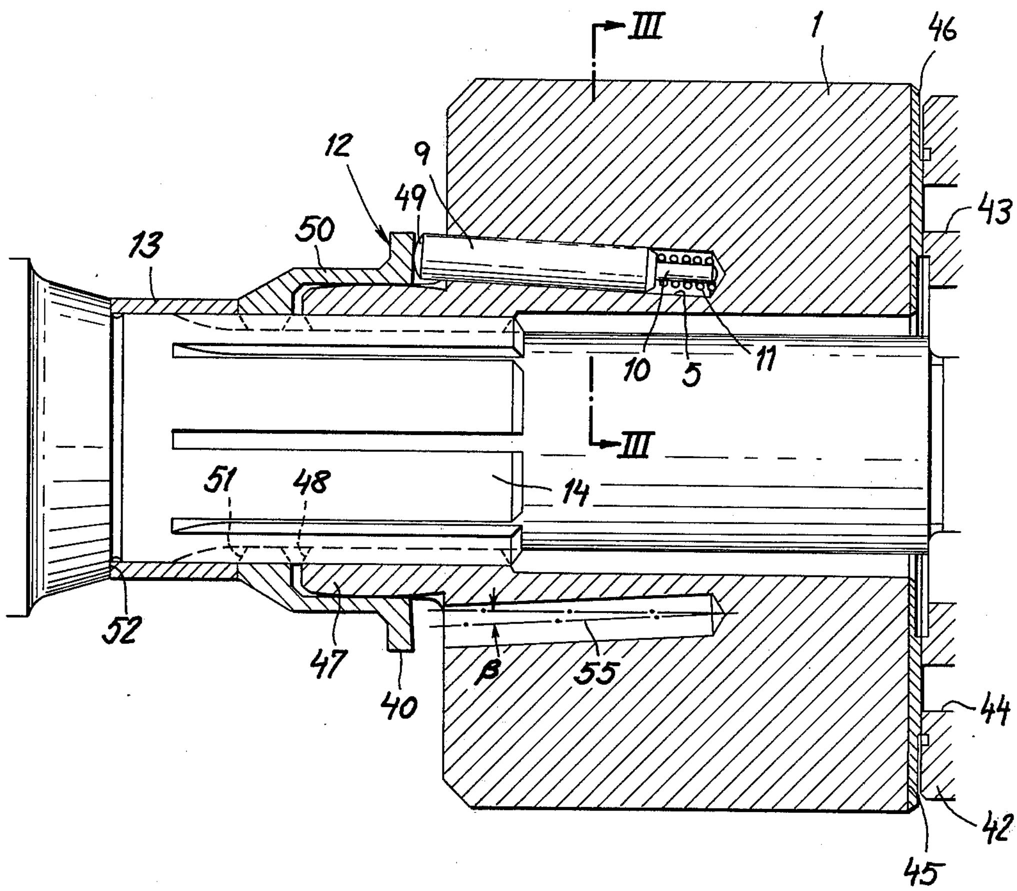


FIG. 1

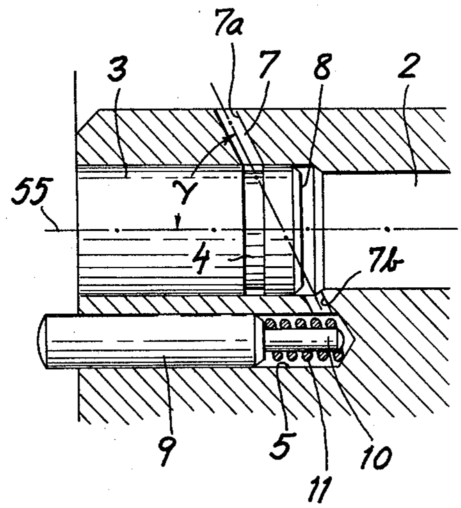


FIG. 2

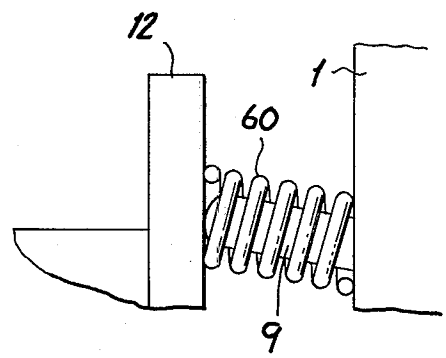


FIG. 5

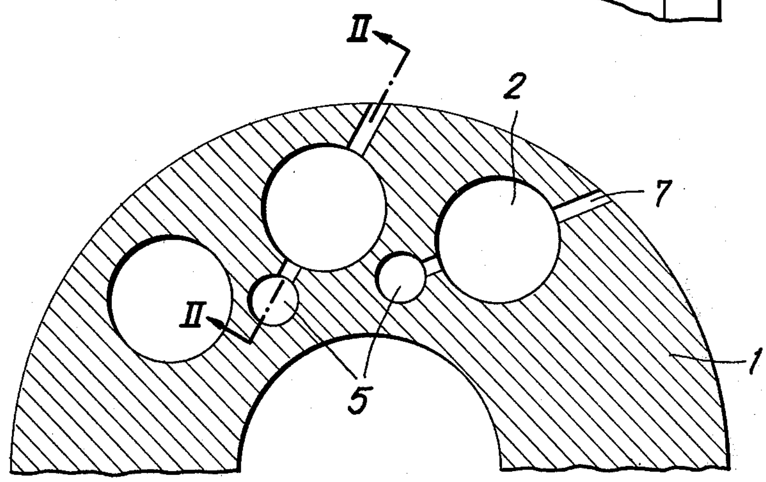


FIG. 3

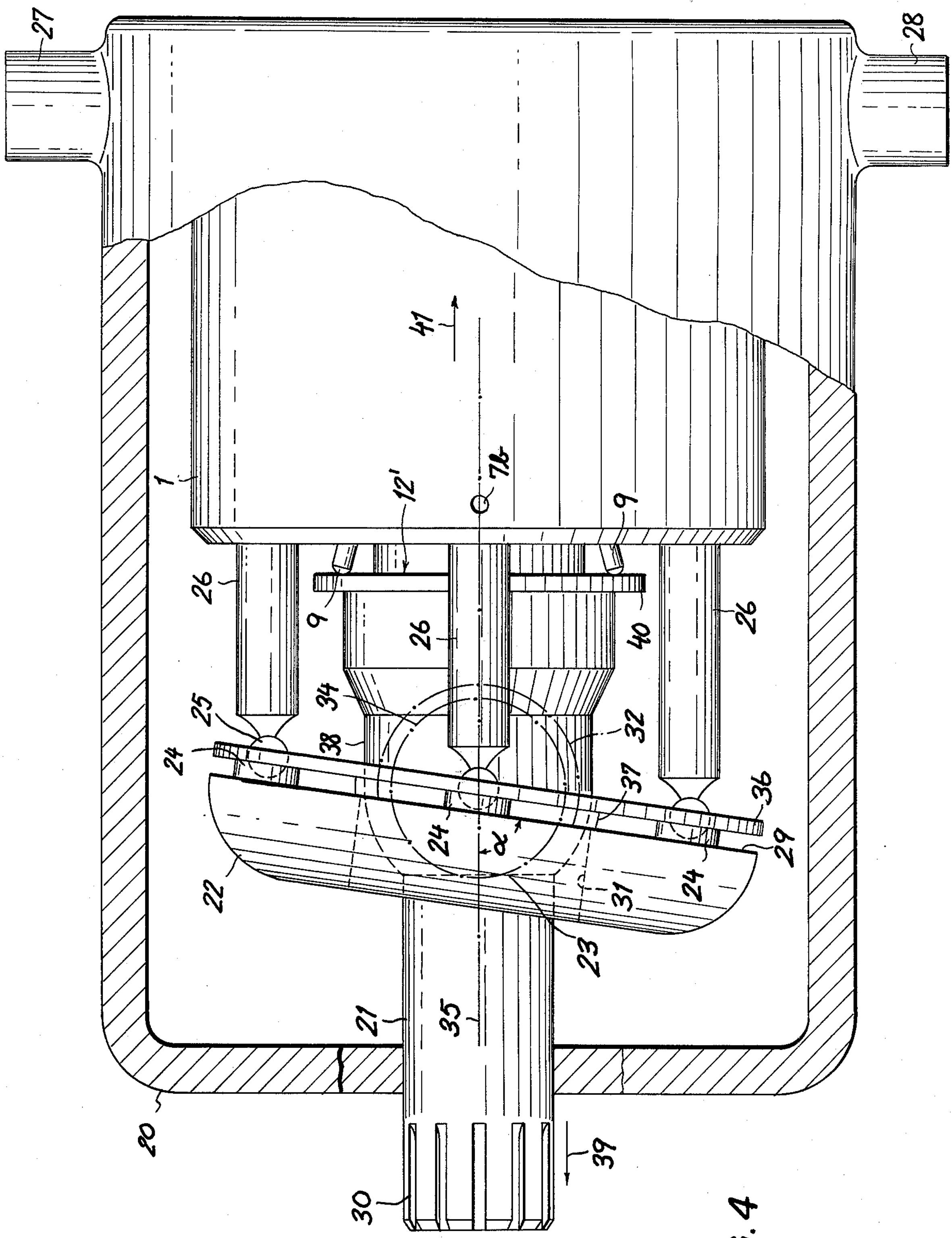

27
28
41
1
7b
12'
9
9
26
26
26
40
25
34
32
24
24
24
38
37
36
29
22
α
23
31
21
35
20
39
30

FIG. 4

AXIAL-PISTON MACHINE

FIELD OF THE INVENTION

The present invention relates to axial-piston machines and, more particularly, to an axial-piston hydrostatic pump or a motor having a cylinder barrel or drum which is held under pressure against a fluid-distribution surface at which a fluid pressure is developed.

BACKGROUND OF THE INVENTION

An axial-piston machine, e.g., an axial-piston pump or motor, also referred to as a hydrostatic pump or motor, may comprise a cylinder drum or barrel which is provided with an array of angularly equispaced cylinder bores (working cylinders), the pistons of which are axially shiftable by mechanical action or hydraulic force, depending upon whether the machine is operative as a pump or motor. In an axial-piston pump, for example, the drum may be rotated with respect to a fixed control plate, inclined about an axis perpendicular to the axis of the drum, the control plate being at an angle to the drum axis so that, as the drum is rotated, e.g., by a shaft or the like, pistons are forced into the respective bores at one side and are permitted to emerge from the respective bores at the other side. As the drum is rotated, each piston progressively is driven into the respective working cylinder and drawn therefrom, thereby decreasing and increasing the volume of the working chamber alternately during each rotation of the cylinder drum. The latter is provided with ports opening into each of the chambers at the base of the drum and slidably engages a fluid-distribution surface provided with openings respectively communicating with an intake fitting and a discharge fitting of the machine. The intake fitting communicates with an opening which registers with the cylinders as the volume of each working cylinder increases through the region subtended by this opening, thereby enabling the hydrostatic medium (hydraulic fluid) to be drawn into the individual cylinders, whereas the discharge fitting communicates with the cylinders via an opening in the region in which the cylinder volumes contract so that hydraulic fluid is displaced through this opening under pressure.

As axial-piston hydrostatic motor, similarly, may comprise a cylinder drum rotatable about its axis and an array of axially displaceable pistons cooperating with an inclined control member which permits the stroke of the piston to increase as the drum rotates toward one side, but reduces the extent to which the piston can emerge from a working cylinder toward the other side of the drum path. Consequently, when fluid is supplied under pressure over part of the control surface, the tendency of the piston to increase their extension in this region causes a rotation of the drum. Machines of this type are collectively referred to as hydrostatic axial-piston machines or as swash plate pumps and motors.

Axial-piston machines of the aforementioned type are employed with rotatable or stationary shafts, with shafts coupled to the cylinder drums or the inclined plate, or with various other means for driving the cylinder drum or deriving torque from the rotation thereof.

For example, in a driven-flange-type of hydrostatic machine, the inclined flange or disk may be mounted upon a shaft which is coupled with the cylinder drum while the latter rotates upon a fixed shaft inclined to the first-mentioned driven shaft. In these systems it is known to provide between the fixed shaft or stub shaft upon which the cylinder drum is journaled, a hydraulic system exerting fluid pressure on the drum so as to urge it axially in the direction of the fluid-distribution surface. This is especially desirable when the drum is mounted with limited axial displaceability upon the stationary shaft. In general, the hydraulic means may include surfaces on the drum and on the shaft which define between them oppositely effective piston surfaces when hydraulic fluid from one or some of the working cylinders is delivered to the space between these surfaces. Arrangements have been proposed in which two sets of surfaces are provided, one of which is in constant communication with the low-pressure side of the hyrostatic machine while the other set is in fluid communication with the high pressure side thereof.

These hydraulic devices work substantially uniformly around the entire periphery of the drum-support shaft and thus the axial force applied to the cylinder drum resists uniformly the buildup of pressure at the interface between the fluid-distribution surface and the drum. Since the pressure on the high pressure side of this surface will always be larger than the pressure on the other side of the surface, the forces applied to the cylinder do not necessarily balance and can exert a twisting action preventing proper positioning of the cylinder drum or causing the latter to bind against the shaft. Where bearings are provided between the shaft and the drum, these bearings show excessive wear because of the nonuniformity of force distribution.

In one system for providing a fluid-pressure bias to hold the cylinder drum, which is mounted for rotation on a central shaft rigid with the housing with axial play, against the fluid-distribution surface, a sleeve is journaled upon the drum shaft or axially seated thereagainst and defines with the drum a pressurizable compartment chargeable with a fluid medium, e.g., the working medium of the machine, to press the base of the cylinder drum against this fluid-distribution surface.

It is also known to use such a sleeve (axially seated against the shaft or axle) to define two pressurizable chambers or compartments with the drum, the chambers being effective upon pressurization to retain the drum against the fluid-distribution surface. To this end, one of the chambers is in fluid communication with the high-pressure passages of the machine (high-pressure side) while the other chamber is in fluid communication with the low-pressure passages or low-pressure side thereof.

A similarly functioning prior-art arrangement provides mutually engageable abutments on the support shaft, which is mounted in the housing with axial play, and upon the drum, the aforementioned pressurizable compartment or chamber being formed between the shaft and the housing so that, upon pressurization of the chamber, the shaft draws the drum against the fluid-distribution surface.

In all of the aforedescribed systems, the working chambers are designed to provide an axial force to the drum and it is a precondition of effective operation of such systems that the drum be mounted with no lateral or radial play. When such play is present, e.g. as a result of manufacturing tolerances and wear of the parts, the pressure at the high-pressure side of the fluid-distribution surface urging the drum away from the latter is substantially greater than the similarly directed pressure at the low-pressure side. As a consequence, canting of the drum may occur with all of the disadvantages which are generally associated with misalignment of rotary members.

Furthermore, when the drum is mounted with some freedom of axial displacement, the restoring force can be generated by a spring and by overdimensioning slightly the surface in the cylinder head which is effective in the direction opposite the pressure at the fluid-distribution surface. The spring also provides force in the absence of hydraulic pressure. These forces are relatively small and thus it has been necessary to provide the sealing surface area at the fluid-distribution surface with small dimensions so the axial force on the drum, determined by the product of the interfacial pressure and sealing surface area will be relatively small. Since the surface is small, wear can be pronounced and large quantities of the hydraulic medium may pass, at the worn sealing surfaces, as leakage into the housing.

The term "fluid-distribution surface" as described above is intended, in accordance with the present invention, to refer to the surface at which the cylinder passages come into fluid communication with the inlet and outlet ports and at which the pressure is developed which urges the cylinder drum axially away from this surface. The fluid-distributing surface may be formed directly in the housing and may be juxtaposed directly with the base of the drum or may be formed between the drum and a fixed fluid-distribution or valve plate and the drum. When the nonrotatable valve plate is axially shiftable, however, the distribution surface will generally be that norotatable surface of the housing which is juxtaposed with the plate and the latter will be considered an axially movable part of the drum for the present purposes. It should also be understood that the principles described below are intended to be applicable to so-called inclined-disk axial-piston machines in which the drum is rotatable relatively to the inclined plate against which the pistons react, and to a driven-flange machine in which this plate is rotated about its axis inclined to the drum axis and the drum is entrained therewith.

OBJECTS OF THE INVENTION

It is the principal object of the invention to provide an improved axial-piston machine in which the aforedescribed disadvantages can obviated.

Still another object of this invention is to provide a machine of the character described with improved means for urging the cylinder drum against the fluid-distribution surface to avoid the difficulty mentioned earlier whereby the force at this surface against the drum is unbalanced between the high-pressure side and the low-pressure side.

Still another object of this invention is to provide a means for urging the drum of an axial-piston machine against its fluid-distribution surface whereby the sealing lands of the drum can have an increased surface area by comparison to earlier axial-piston machines.

SUMMARY OF THE INVENTION

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, in an axial-piston machine in which the cylinder drum is provided with a plurality of pressing cylinder bores; each connected to one or more working cylinders of the drum of the axial-piston machine or connected in groups to respective working cylinders, the pressing cylinders receiving respective pressing pistons bearing against the axially fixed member, e.g., the shaft, for applying to the cylinder drum a force balancing the force at the fluid-distribution surface in the region of the associated working piston. In other words, when the working cylinder bore communicates with the associated port at the high-pressure side of the fluid-distribution surface there is a greater force in the region of the high-pressure side urging the corresponding side of the drum axially away from the fluid-distribution surface and there is developed at the pressing cylinder bore an elevated pressure which is applied to the respective pressing piston and then to the axially fixed member to counteract the increased pressure at the fluid-distribution surface. Of course, the working cylinders should not be able to communicate with one another through the pressing cylinders.

For each working cylinder or at least for each n working cylinders, where n is an integer such **2**, **3**, etc., there is provided at least one pressure or force-generating bore in the manner described. When a large number of working cylinders are provided in the cylinder drum, it may be advantageous to associate a pressurizing cylinder with each second, third, etc., working cylinders. Normally, however, each working cylinder will be associated with one pressing cylinder. Of course, as noted earlier, a number of pressing cylinders may be provided for each working cylinder. According to an important feature of the present invention, the pressing cylinders are disposed in an annular array inwardly of the working cylinders and have pistons inclined in the direction of the axis of rotation of the drum and bearing against a flange axially fixed to the shaft.

Each pressurizing cylinder is preferably disposed in the cylinder drum adjacent the respective working cylinder and communicates therewith in the manner described in greater detail hereinafter. In this manner, the half of the drum exposed to high pressure at the fluid-distribution surface is urged with the greatest force (by the pressing cylinders) in the counteracting direction and the half of the drum exposed to the lowest pressure at the fluid-distribution surface receives a correspondingly lower pressure from the pressurizing cylinders on this side of the drum. Each of the working cylinders and the associated pressing cylinder can be connected by a transverse bore.

According to still another feature of the invention, each of the working-cylinder bores is provided with a guide bushing for the respective working piston, composed of a material which in contact with the working piston offers frictional characteristics and wear characteristics which are desirable (i.e., low-sliding friction and minimum piston wear). In the present case, I dispose the connecting bore so that the latter opens immediately ahead of the inner end of the bushing into the working cylinder, i.e., with respect to the cylinder head, prior to the guide bushing.

To prevent the working fluid from passing out of the cylinder bore in a leakage path all around the guide bushing, the latter is provided with a circumferential groove into which a vent passage in the wall of the cylinder drum opens. The depressurizing and vent passages are advantageously inclined with respect to the axes of the working piston and the pressure cylinder and may be inclined as with the connecting passage mentioned above so that the two passages may be formed as a single linear bore in one machining operation. Advantageously, the passages lie along a chord of the cylinder drum and are inclined outwardly away from the fluid-distribution surface.

The axes of the pressurizing cylinders can, of course, be parallel to the cylinder-drum axis although it is preferred to have the pressure cylinder axes inclined to this cylinder drum axis away from the fluid-distribution surface. Each of the pressurizing cylinders, therefore, may have an axis lying in a plane through the cylinder drum axis and may be offset from a plane through the cylinder drum axis and the axis of the working cylinder with which the pressure cylinder communicates. The axis of each pressurizing cylinder may include an acute angle with the cylinder drum axis, the angle being selected so as to provide the desired axial force component for a given pressure behind the piston in the pressurizing cylinder and the desired moment when acting upon the flange fixed to the shaft. It will be appreciated that substantially all of the pressure generated in the pressurizing cylinder will be transmitted directly to the shaft when the piston therein is parallel to the shaft axis and this force may be excessive. By selecting an acute angle in the manner described, the moment of force contributed by each pressurizing piston may be varied accordingly. When the axes of the pressurizing pistons lie along a cone whose apex lies toward the fluid distribution surface the moment attributed to the pressurizing pistons is reduced by comparison to an arrangement in which the axes lie along a cylinder centered on the axis of the cylinder drum and the pressurizing pistons are parallel to the cylinder drum axis. When, however, the conical surface defined by the axes of the pressurizing pistons has its apex turned away from the fluid-distribution surface, the moment is increased by comparison with that developed by pressurizing pistons parallel to the axis of the cylinder drum.

According to still another feature of the invention, the cylinder drum is held against the fluid-distribution surface even in the absence of working fluid pressure by providing, in one or more of the pressurizing-cylinder bores a coil spring which bears upon the pressurizing piston and reacts against the cylinder. Preferably the springs are disposed symmetrically with respect to the cylinder-drum axis and are disposed in pressurizing cylinders angularly equispaced about this axis. Each of the pressurizing cylinders can, of course, receive one of the springs which may be of the compression coil type.

Each of the pressurizing pistons may, moreover, be formed with an extension at least partially filling the spring-receiving space so as to decrease the fluid volume thereof and thereby reduce dead space in the system.

The pressurizing pistons can bear against an abutment ring or crown which, in turn, bears axially upon the shaft away from the fluid-distribution surface. This crown can be formed with a ball-shaped or conical cap-like configuration cooperating with a complementary formation on a retaining ring holding the shoes of the working pistons against the inclined control plate of the machine. Of course, when the crown is rigid with the shaft, i.e., has no freedom of axial displacement relative thereto, a rigid support is provided for the shoes and the retaining plate must therefore be made so as to have some play between the shoes and the crown and thus to enable thermal expansion and contraction to occur without binding and to allow for assembly of the parts.

DESCRIPTION OF THE DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. **1** is an axial cross-sectional view through a portion of a cylinder drum embodying the present invention;

FIG. **2** is a cross-sectional view representing a detail of FIG. 1 and taken generally along the line II — II of FIG. 3;

FIG. **3** is a cross-sectional view taken generally along the line III — III of FIG. 1 with the pistons and guide bushings removed;

FIG. **4** is a side-elevational view, partly broken away of an axial-piston machine according to the invention; and

FIG. **5** is a detail view illustrating another embodiment of the invention.

SPECIFIC DESCRIPTION

Referring first to FIG. **4**, it will be apparent that the axial-piston machine, operated as a pump in the embodiment described, comprises a housing **20** which is broken away to reveal a shaft **21** whose splines **30** may be connected with a driving source, e.g., an electric or internal-combustion engine. The shaft **21** passes through an opening **31** in a control disk **22** which is mounted via a lug **32**, shown in dot-dash lines, for pivotal displacement in a bearing **33** of the housing, likewise shown in dot-dash lines. The pivotal movement, about an axis perpendicular to the plane of the paper, can be effected by a servomechanism or manual means adjustable externally of the housing **20.**

The control plate **22** is formed with a surface **29** lying in a plane transverse to the axis **35** of the shaft **21** and a cylinder drum **1** and the angle α between the surface **29** and the axis **35** can therefore be adjusted to vary the displacement of the pump.

A plurality of shoes **24** slidingly engage the surface **29** and are held thereagainst by a retaining plate **36** having a ball-shaped or conical hub **37** engaging a complementary portion **38** of a support crown **12'** functionally similar to the support crown **12** shown in greater detail in FIG. **1** and axially bearing upon the shaft **21** in the direction of arrow **39.** The support crown **12'** is keyed to the shaft for rotation therewith.

Each of the shoes **24** has a ball-shaped socket receiving the generally ball-shaped head **25** of respective working pistons **26** which are axially shiftable in respective cylinders **2** (FIG. **3**) angularly spaced about the axis **35** and formed in the cylinder drum **1.** The latter is keyed to the shaft **21** as well and can be rotated by this shaft. The auxiliary or pressurizing pistons **9** bear against a flange **40** of the crown. The housing **20** is also provided with a fluid-distribution surface (FIG. **1**) and with a pair of fittings **27, 28,** serving as the high-pressure and low-pressure ports respectively.

When the shaft **21** is rotated, the drum **1** is entrained angularly about the axis **35** so that the working pistons **26** are alternately driven into the drum and drawn therefrom to displace the hydraulic fluid and induce it to flow into the cylinder bores, respectively, thereby effecting displacement at a rate determined by the pivotal angle of the control plate 22. The pistons 9 bear upon the crown 12′ and thus apply pressure on the shaft in the direction of arrow 39, the reaction pressure represented by arrow 41 serving to hold the cylinder drum against the fluid-distribution surface.

In the embodiment illustrated in FIG. 1, the fluid-distribution surface is provided by a stationary plate 42 which is formed with kidney-shaped ports 43 and 44, respectively, communicating with the ports 27 and 28, the rear end 45 of the cylinder drum 1 being provided with a low-friction bearing disk 46 at which the cylinder bores 2 open. The cylinder drum is also formed with a neck 47 whose inwardly extending splines 48 engage in the flutes of a splined portion 14 of the shaft for rotatable entrainment of the cylinder drum with the shaft. The crown 12 of the embodiment shown in FIGS. 1 – 3 has a cylindrical portion 50 surrounding the neck 47 and terminating in the transverse flange 40 against which the pressure pistons 9 bear with rounded ends 49. The cylindrical portion 50, at its upper end, is turned inwardly and has a fluted portion 51 engaging the spline shaft 14. The crown member 12, moreover, bears axially against a sleeve 13 which abuts a shoulder 52 of the shaft.

In accordance with the present invention, the cylinder drum is provided with a plurality of annularly equispaced working cylinder bores 2 whose axes are parallel to one another and to the axis 35 of the cylinder drum. Each of the working cylinders 2 receives a guide sleeve 3 (shown in elevation in FIG. 2) through which the respective working piston 26 passes and which is formed along its outer circumference with a depressurizing roof 4.

Adjacent each working cylinder 2, the cylinder drum 1 is formed with an auxiliary or pressurizing cylinder bore 5 which has an axis 55 defining an acute angle with the axis of the β cylinder drum such that all of the axes 55 lie along a conical surface whose apex is turned toward the fluid-distribution surface. A linear bore 7 is inclined to the axis 55 (see FIG. 2) at an angle γ so that it may form a relief or vent portion 7*a* and a connecting portion 7*b* as described previously. The connecting portion communicates between the pressurizing cylinder 5, behind its piston 9, and the cylinder bore 2 behind the guide bushing 3 thereof. The leading edge 8 of the guide bushing can thus be seen to be set back to the left from the passage 7*b*. The guide bushing 3 has an outwardly open circumferential relief group 4 which communicates with the portion 7*a* of the bore 7 and opens at the periphery of the drum as shown for one of the cylinder bores in FIG. 4.

Each of the pressurizing cylinders 5 receives a piston 9 having an axial projection 10 partly filling the bore behind this piston and surrounded by a spring 11 which biases the piston 9 to the left and the cylinder drum 1 to the right. Each piston 9 bears against the crown 12 which, in turn, is seated axially against the shaft 14. Consequently, the pressure buildup in each of the working cylinders 2 is communicated to the respective cylinder bore 5 and drives its piston 9 to the left to bias that side of the cylinder drum against the fluid-distribution surface 42 and maintain a tight seal with the fluid-distribution surface, limiting leakage therefrom.

In FIG. 5 it can be seen that a spring 60 may be provided around one or more of the pistons 9 between the crown 12 and the cylinder drum 1 to urge the latter in the direction of the fluid-distribution surface. In this case, the springs 11 may be omitted.

I claim:

1. In an axial piston machine having a shaft, a cylinder drum coupled with said shaft for rotation therewith, a plurality of working cylinders formed in said cylinder drum in an annular array, respective working pistons received in said working cylinders and axially shiftable therein while bearing upon an inclined surface at one side of said cylinder drum, and a fluid-distribution surface extending transverse to the axis of said cylinder drum at the other side thereof and communicating with said working cylinders, the improvement wherein said cylinder drum is formed with a plurality of pressing cylinders within said array each communicating with at least one of said working cylinders for pressurization thereby, a pressing piston received within each of said pressing cylinders and displaceable therein, and an annular abutment retained on said shaft against axial displacement away from said fluid-distribution surface and engaged by said pressing pistons whereby said cylinder drum is urged in the direction of said fluid-distribution surface, said abutment rotating with said shaft, each of said working cylinders being connected to a respective pressing cylinder by a respective connecting passage formed in said cylinder drum, each of said working cylinders being formed with a guide bushing at said side of said cylinder drum, each of said connecting passages opening into the respective working cylinder behind the respective guide bushing.

2. The improvement defined in claim 1 wherein each of said guide bushings is formed with a circumferential relief groove and said cylinder drum is formed with respective relief passages each communicating with a respective one of said relief grooves.

3. The improvement defined in claim 2 wherein the relief passage and the connecting passage of each working cylinder are aligned and form parts of a bore extending into said drum and inclined to the axis of the respective working cylinder.

* * * * *