United States Patent [19]

Miyao et al.

[11] **3,866,518**

[45] **Feb. 18, 1975**

[54] **FLUID PRESSURE DEVICE OF THE AXIAL PLUNGER TYPE**

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[22] Filed: **Dec. 27, 1972**

[21] Appl. No.: **319,031**

[30] **Foreign Application Priority Data**

Dec. 27, 1971 Japan 46-3539

[52] **U.S. Cl.** **91/488**
[51] **Int. Cl.** **F01b 13/04**
[58] **Field of Search** 91/472–507; 308/237, 241

[56] **References Cited**

UNITED STATES PATENTS

2,934,480	4/1960	Slomin	308/241
3,075,472	1/1963	Garnier	91/488
3,263,623	8/1966	Alexanderson et al.	91/488
3,280,758	10/1966	Leaming et al.	91/499
3,280,758	10/1966	Leemig et al.	91/499
3,297,552	1/1967	Gisser et al.	308/237
3,709,107	1/1973	Alger	91/499
3,726,189	4/1973	Rubery	91/507
3,768,378	10/1973	Adam et al.	91/499

FOREIGN PATENTS OR APPLICATIONS

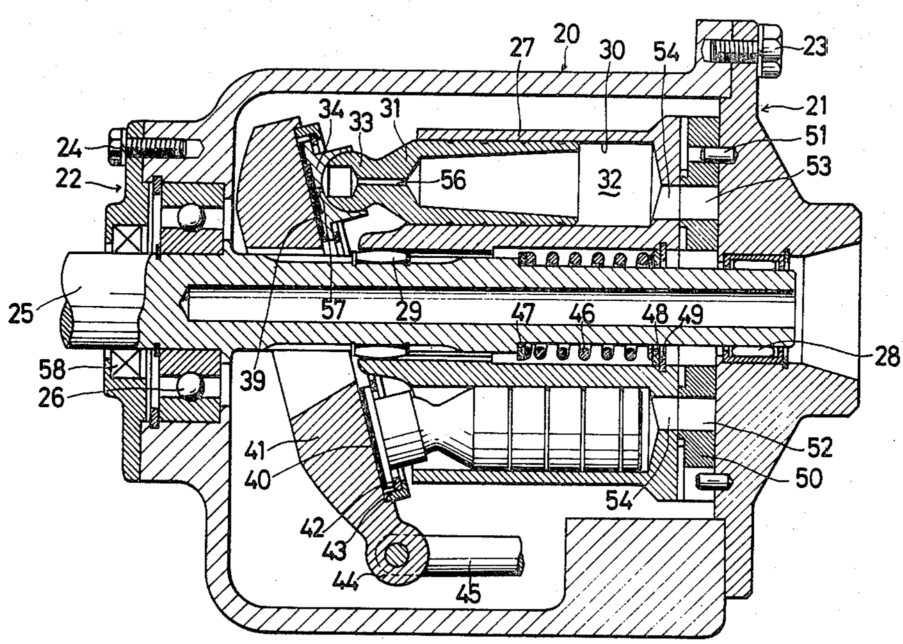
716,871	8/1965	Canada	91/472
497,775	12/1948	Canada	91/472
646,228	8/1962	Canada	91/488
1,251,200	1/1961	France	91/498

Primary Examiner—William L. Freeh
Attorney, Agent, or Firm—Oblon, Fisher, Spivak, McClelland & Maier

[57] **ABSTRACT**

A fluid pressure device of the axial plunger type including a housing, a rotatable shaft within the housing, a rotatable cylinder block operatively connected to the shaft and having a plurality of axial bores, plungers slidably mounted, respectively, within the bores, a valve plate located in abutment with an end surface of the cylinder block and having inlet and outlet ports which communicate successively with the bores as the cylinder block rotates, a swash plate pivotally supported upon the housing and operatively connected to the plungers for causing the plungers to reciprocate, and plunger shoes positioned between the plungers and the swash plate, the shoes being made of either a high tensile aluminum alloy, titanium, or a high tensile titanium alloy and comprising a slidable bearing surface made of a high load-bearing alloy which is adapted to bear against a planar surface of the swash plate.

6 Claims, 13 Drawing Figures



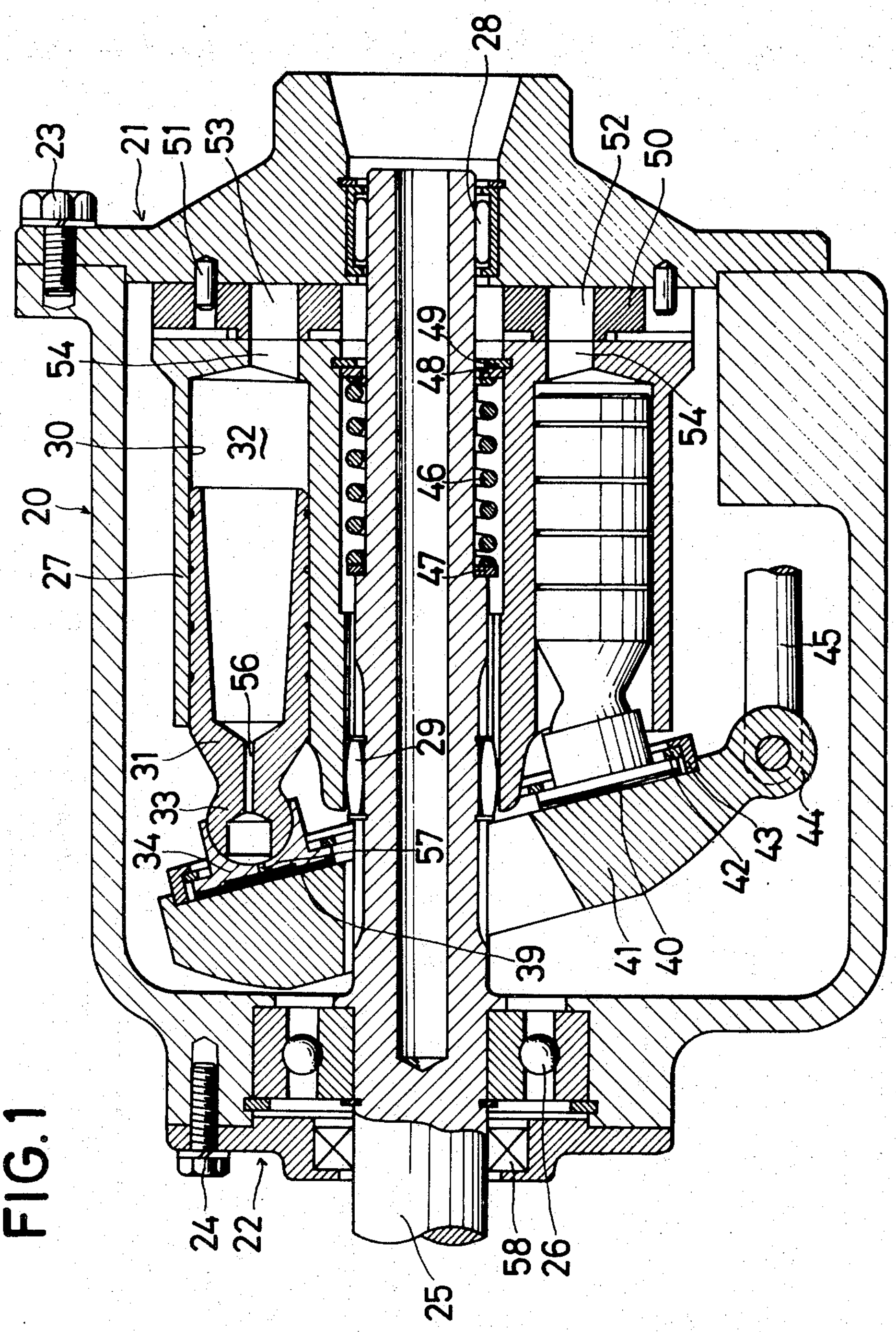

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FIG.1

FIG. 2

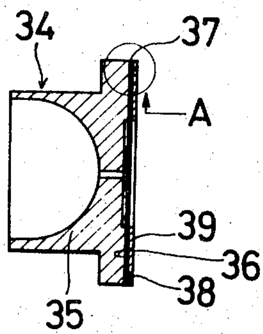
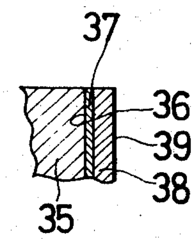


FIG. 3



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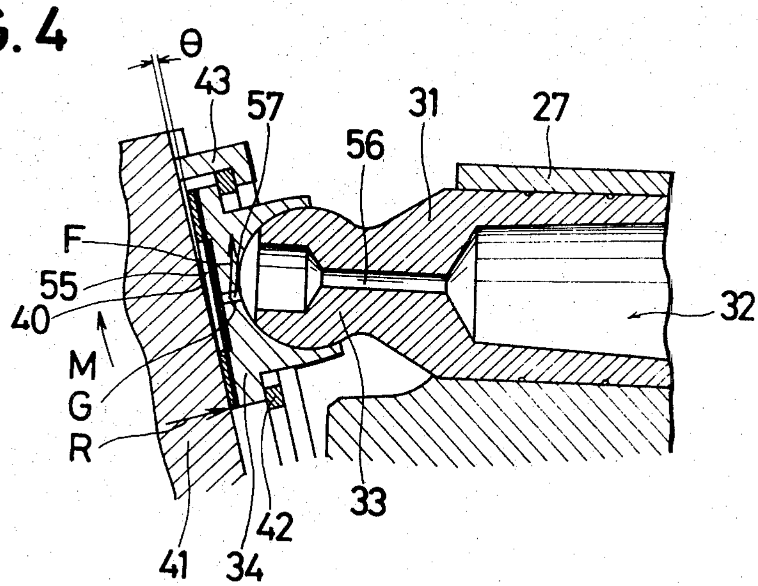

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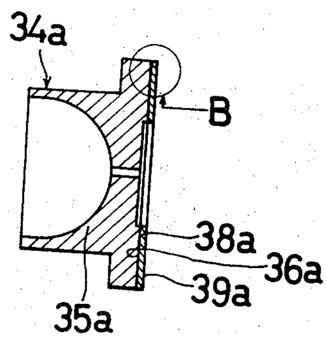

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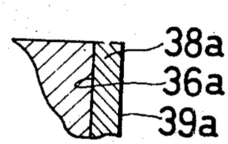

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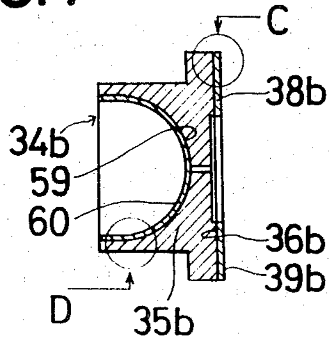


FIG. 8

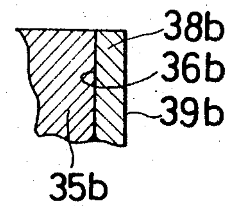


FIG. 9

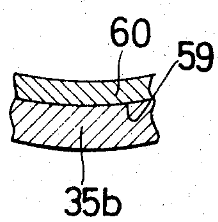


FIG. 10

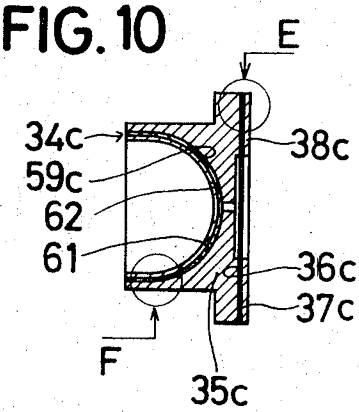


FIG. 11

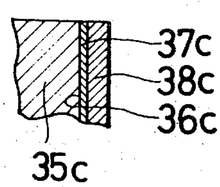


FIG. 12

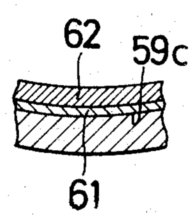
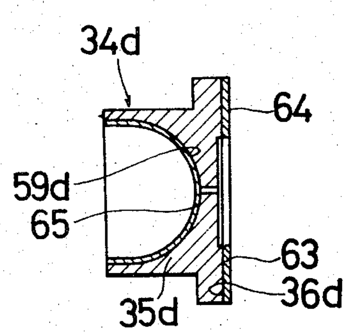


FIG. 13



FLUID PRESSURE DEVICE OF THE AXIAL PLUNGER TYPE

BACKGROUND OF THE INVENTION

The present invention relates generally to fluid pressure devices, and more particularly to plunger shoes for use in fluid pressure devices of the axial plunger type which are capable of being operated as either a pump or a motor.

Fluid pressure devices of the type mentioned are well known in the art. Such devices include a plurality of plungers slidably disposed, respectively, within a plurality of cylindrical bores of a cylinder block and operatively engaged with an inclined planar surface of a stationary swash plate so that relative movement between the plungers and the swash plate is accomplished upon operation of the device.

The devices further include a plurality of plunger shoes interposed between the plungers and the swash plate for absorbing the plunger thrust forces due to the relative movement between the plungers and the swash plate. More particularly, each plunger shoe has a spherical socket portion which pivotally supports a spherical outer end of the associated plunger mounted therein. A sliding end surface of the plunger shoe bearing against the planar surface of the swash plate has a central annular recess which is adapted to receive fluid pressure thereby providing a hydraulic balancing force which also acts as a hydraulic bearing means for providing lubrication between the plunger shoe and the swash plate.

However, due to the fact that the sliding surface of the shoe will be exposed to high load and high rotational speed conditions, phenomena, such as for example, excessive wear and heating of the shoe's sliding surface will occur. These phenomena will of course substantially restrict the operation of the device under such high pressure or high rotational speed conditions.

In addition, it should also be noted that the center of gravity of each plunger shoe does not correspond to the geometrical center of the spherical surface of each plunger. That is, the center of gravity of the plunger shoe is displaced toward the planar surface of the swash plate. Thus the plunger shoe is subjected, at the center of the spherical surface thereof, to a moment due to centrifugal force which is proportional to the weight of the plunger shoe and the square of the rotational speed of the device when the device is in its operational state. This results in the condition wherein the plunger shoe becomes inclined with respect to the planar surface of the swash plate.

Furthermore, the conventional plunger shoe is generally made of a material such as for example, phosphor bronze which has the necessary bearing ability, however, the specific gravity of phosphor bronze is large and, therefore, the moment which tends to cause the plunger shoe to become inclined with respect to the swash plate becomes correspondingly large. Consequently, the plunger shoe is urged at one end thereof to contact the planar surface of the swash plate along a lineal locus and consequently a satisfactory film of lubrication cannot develop between the plunger shoe and the swash plate planar surface, and further, metallic contact between the plunger shoe and the planar surface can result. This of course hastens wear of the plunger shoe, which is generally made of a softer material than the swash plate, and causes the plunger shoe to become excessively heated which further hastens the wear thereof. Thus, the effective service life of the plunger shoe will be substantially reduced.

Still further, although some amount of leakage between the relative sliding surfaces of the plunger shoe and the swash plate is desirable for lubrication therebetween, leakage may become excessive due to the increased inclination of the plunger shoe relative to the swash plate so that the volume efficiency of the fluid pressure device will be reduced. It is additionally understood that the various disadvantages mentioned heretofore will of course be increased during operation of the device at high load and high speed conditions.

Also, while it is necessary that in order to prevent deformation of the plunger shoe that it has a higher yield strength, it is also required that the shoe be malleable so that the shoe may be caulked to the spherical outer end of the associated plunger.

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide an improved fluid pressure device of the axial plunger type which does not exhibit the above mentioned disadvantages.

Another object of the present invention is to provide an improved fluid pressure device of the axial plunger type wherein each plunger shoe has a high wear-resistance and a high heat-resistance.

Still another object of the present invention is to provide an improved fluid pressure device of the axial plunger type wherein the plunger shoe is made of a material such as a high tensile aluminum alloy, titianium, or a titanium alloy which is of relatively small specific gravity and of high tensile strength, the plunger shoe comprising a sliding surface made of an alloy which exhibits high load-bearing properties.

Yet another object of the present invention is to provide an improved fluid pressure device of the axial plunger type wherein the sliding surface of the shoe is made of an aluminum alloy such as for example, an alloy of aluminum (92–96percent) and silicon (4–8percent) respectively, which exhibits excellent structural adaptability, high wear-resistance, and high heat-resistance.

It is a further object of the present invention to provide an improved fluid pressure device of the axial plunger type wherein the sliding surface of the shoe is made of a material, such as for example, a copper alloy, which may be for example, phosphor bronze, high-lead phosphor bronze, or the like, or a copper alloy of sintered material which exhibits excellent structural adaptability, high wear-resistance, and high heat-resistance.

A still further object of the present invention is to provide an improved fluid pressure device of the axial plunger type wherein the plunger shoe further comprises a spherical socket portion for receivably mounting the spherical outer end portion of the associated plunger, the spherical socket portion including a film made of an alloy of aluminum and silicon, a copper alloy or a copper alloy of sintered material which exhibits excellent structural adaptability and a high wear-resistance.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features, and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawings in which like reference characters designate like or corresponding parts throughout the several views, and wherein:

FIG. 1 is a cross sectional view of a fluid pressure device of the axial plunger type representing one embodiment of the present invention;

FIG. 2 is an enlarged cross sectional view of a plunger shoe for use within the fluid pressure device of FIG. 1;

FIG. 3 is an enlarged view of designated portion A of FIG. 2;

FIG. 4 is an explanatory view disclosing the function of the present invention;

FIG. 5 is a view similar to that of FIG. 2, disclosing however, a second embodiment of the plunger shoe;

FIG. 6 is an enlarged view of designated portion B of FIG. 5;

FIG. 7 is a view similar to that of FIG. 2, disclosing however, a third embodiment of the plunger shoe;

FIG. 8 is an enlarged view of designated portion C of FIG. 7;

FIG. 9 is an enlarged view of designated portion D of FIG. 7;

FIG. 10 is a view similar to that of FIG. 2, disclosing however, a fourth embodiment of the plunger shoe;

FIG. 11 is an enlarged view of designated portion E of FIG. 10;

FIG. 12 is an enlarged view of designated portion F of FIG. 10; and

FIG. 13 is a view similar to that of FIG. 2, disclosing however, a fifth embodiment of the plunger shoe.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and more particularly to FIGS. 1,2, 3 and 4 thereof, a hydraulic fluid device of the axial plunger type includes a housing **20** having two end plates **21** and **22** respectively secured thereto by screw or bolt means **23** and **24**. An axial drive shaft **25** is rotatably supported at one end of the housing **20** by means of bearings **26** and extends through a rotatable cylinder block **27** to the end plate **21** wherein the drive shaft **25** is rotatably supported by means of bearings **28**, the bearings **26** preventing the drive shaft **25** from experiencing any axial movement. The drive shaft **25** is operatively and drivingly connected to the cylinder block **27** through a plurality of connecting pins **29** circumferentially positioned around the drive shaft **25** whereby the cylinder block **27** is adapted to rotate together with the drive shaft **25**.

The cylinder block **27** contains a plurality of axially aligned, circumferentially positioned longitudinal bores **30** in which one of a plurality of plungers **31** is respectively slidably mounted so as to define therein a hydraulic piston chamber **32**. Although only two plungers **31** are shown in FIG. 1, there may be for example, nine plungers **31**, as is known in the art. The outer ends **33** of the plungers **31** are of spherical configuration and are universally connected to and pivotally mounted within plunger shoes **34**, that is, the shoes **34** have spherical socket portions for receiving the outer ends **33** thereby serving as ball bearings.

As viewed in FIGS. 2 and 3, each of the plunger shoes **34** includes a body portion **35** made of a high tensile aluminum alloy, titanium, or a high tensile titanium alloy, which is processed with grid blast at an end surface **36** thereof. Upon the end surface **36** there is applied a layer of molybdenum **37** upon which a high load-bearing alloy **38**, such as for example, an alloy of aluminum and silicon or phosphor bronze is further applied. The application of the molybdenum layer **37** is effective to firmly secure the alloy layer **38** thereon. The alloy of aluminum and silicon comprises respective proportions of aluminum and silicon of **92-96:4-8** % and is subsequently subjected to a forging process. The resulting alloy of aluminum and silicon is thus excellently adapted for the high-load and high-speed conditions of the device.

A sliding end surface **39** of the shoe **34** engages a sliding planar surface **40** of a swash plate **41** for the purpose of facilitating reciprocation of the plungers **31**. A disk-like retainer **42** has a plurality of holes in which the plunger shoes **34** are positioned and a retaining member **43** is secured to the swash plate **41** by means of bolts, not shown, in order to secure the retainer **42**. The shoes **34** are thus maintained in slidable contact with the surface **40** of the swash plate **41**.

The swash plate **41** is supported within the housing **20** by means of trunnions, not shown, which are secured to the housing **20** in a well known manner, the swash plate **41** therefore being adapted to be pivoted about an axis transverse to the axis of the drive shaft **25**. The lower end **44** of the swash plate **41** is mechanically connected to conventional actuating means, not shown, through a connecting link **45** so that the inclination of the swash plate **41** may be automatically or manually controlled in order to adjust the displacement of the plungers **31**.

A coil spring **46** disposed about and anchored to the drive shaft **25** through an annular collar **47** biases another annular collar **48** against a snap ring **49** which is secured to the cylinder block **27**, and thus, biases the cylinder block **27** and a valve plate **50** against the end plate **21**, the valve plate **50** and the cylinder block **27** thereby being urged into face-to-face contact. The valve plate **50** is mounted against the end plate **21** by pin means **51** so that the valve plate **50** is retained against rotation with the cylinder block **27** and is formed with a pair of ports **52** and **53** of the conventional elongate arc-shaped type which are hydraulically connected, respectively, to associated hydraulic systems, not shown. A series of axially extending passages **54** is formed, respectively, within the cylinder block **27** and are successively brought into association with the ports **52** and **53** in a known manner during rotation of the cylinder block **27** so that the hydraulic fluid may be transmitted to and from the hydraulic chambers **32**.

As best shown in FIG. 4, the surface **39** of each plunger shoe **34** has a central annular recess **55** while an axially extending passage **56** provided within each plunger **31** is hydraulically connected to the recess **55** through an orifice **57** formed within the shoe **34**. The recess **55** will thus receive hydraulic fluid when the associated chamber **32** is under pressure and will serve as a hydraulic bearing means acting between the surfaces **39** and **40**. The hydraulic fluid pressure within the recess **55** will produce a thrust upon the shoe **34** which will tend to oppose the plunger thrust, the thrust produced by the fluid pressure within the recess **55** depending upon the leakage flow between the surfaces **39** and **40** and the pressure drop occurring at the orifice **57**. As the gap between the surfaces **39** and **40** increases there will be greater leakage flow therebetween which will in turn cause a greater reduction of fluid pressure within the recess 55 and vice versa. Thus the fluid pressure within the recess 55 is balanced thereby providing a constant gap between the surfaces 39 and 40. An annular sealing member 58 is mounted within, and disposed about, end plate 22 and drive shaft 25 respectively.

Referring now to FIGS. 5 and 6, the plunger shoe 34*a* includes a body portion 35*a* made of a high tensile aluminum alloy, titanium, or a high tensile titanium alloy, and an end surface 36*a* of the body 35*a* which is processed with gridblast and thereafter covered with a high load-bearing alloy 38*a*, such as for example, an alloy of aluminum and silicon or phosphor bronze. Of course, if it is desired, the high load-bearing alloy 38*a* may be secured to the end surface 36*a* by any one of the conventional methods such as for example, friction welding, plating or powder metallurgy. In the instance that the method of plating is utilized, the surface to be plated is initially coated with zinc and is thereafter plated.

In FIGS. 7, 8 and 9, a spherical surface 59 of the shoe 34*b* adapted to receive therein the spherical outer end portion of the associated plunger is processed with gridblast and is thereafter covered with a high load-bearing alloy 60, such as for example, an alloy of aluminum and silicon or phosphor bronze. The remaining structure of shoe 34*b* is similar to that shoe disclosed within the embodiment of FIGS. 5 and 6.

Referring now to FIGS. 10, 11, and 12, a spherical surface 59*c* of the shoe 34*c* initially processed with gridblast is subsequently covered with a layer of molybdenum 61 and is thereafter covered with a high load-bearing alloy 62, such as for example, an alloy of aluminum and silicon or phosphor bronze. The remaining structure of the shoe 34*c* is the same as that shoe disclosed within the embodiment of FIGS. 2 and 3.

In FIG. 13, a base portion 35*d* of the shoe 34*d* is made of a high tensile aluminum alloy, titanium or a high tensile titanium alloy. Upon the surface of the base portion 35*d*, a powdered layer 63 of a high load-bearing alloy, such as for example, an alloy of aluminum and silicon, phosphor bronze, or high lead phosphor bronze is applied and is subsequently treated by applying a proper amount of heat. The powder 63 thus applied has a porous surface 64 so that even if the shoe makes metallic contact with the sliding surface of the swash plate, oil contained within the porous surface will ooze out therefrom due to the heat generated therebetween so as to thereby provide good lubrication. The spherical socket portion of the shoe 34*d* for receiving the plunger is similarly covered with a powder metallurgy material 65 of a high load-bearing alloy whereby the same effect mentioned above can be obtained.

In operation, although this device may function as either a pump or a motor, its operation as a pump will now be described, in which case, the drive shaft 25 is connected to a suitable prime mover, not shown. The drive shaft 25 is rotated by the prime mover and in turn will cause rotation of the cylinder block 27. Therefore, the chambers 32 will sequentially communicate with the low pressure or inlet port 52 of the valve plate 50 and then with the high pressure or outlet port 53 of the valve plate 50 in a conventional manner. At the same time, the plungers 31 and the shoes 34 will be rotated in a circular path around the axis of the drive shaft 25 during rotation of the cylinder block 27, the rotary motion of the plungers 31 and shoes 34 being confined to a locus defined by the inclined position of the swash plate 41 whereby the plungers 31 will be reciprocated within the bores 30. Thus, hydraulic fluid will enter the chambers 32 at the inlet port 52 for low pressure when the plungers 31 are moved on their suction strokes, and will be delivered from the chambers 32 under pressure at the outlet port 53 for high pressure when the plungers 31 are moved on their discharge strokes, a pumping action thereby being accomplished.

In operation of the device as a motor, the inlet and outlet ports are reversed and, therefore, the fluid valved through the port 53 of the high pressure side or inlet side of the valve plate 50 enters the chambers 32 through the passages 54. The fluid pressure within the chambers 32 acts upon the plungers 31 which in turn urge the plunger shoes 34 against the surface 40 of the swash plate 41 so as to effect a sliding motion of the shoes 34 upon the surface 40, this action resulting in rotation of the cylinder block 27 and the drive shaft 25 connected thereto. The hydraulic fluid will thus be transmitted to the chambers 32 from the inlet port 53 for high pressure when the plungers 31 are moved on their suction strokes and will then be delivered from the chambers 32 at the outlet port 52 for low pressure when the plungers 31 are moved on their discharged strokes, a motor action thereby being accomplished.

In either case, the fluid within the chamber 32 is transmitted to the recess 55 so that the hydraulic balancing force between the sliding surfaces of the shoe 34 and the swash plate 41 will be provided, as was noted hereinbefore.

In FIG. 4, G represents the center of gravity of shoe 34 and F represents the centrifugal force exerted at the center of gravity G of shoe 34 during operation of the device. The centrifugal force F increases in proportion to the weight of the shoe and the square of the rotational speed of the device. As shown in FIG. 4, the center of gravity G does not correspond to the geometrical center of the spherical socket surface of the shoe 34 and is biased or displaced toward the sliding surface 40 of the swash plate 41 so that a moment M will be produced, the moment M causing the shoe 34 to become inclined with respect to the sliding surface 40. Therefore, a reaction force R is exerted upon the shoe so as to balance the moment M. As a result, the shoe 34 will be inclined at an angle O.

Now assuming that devices constructed identically will be actuated under the same conditions, the centrifugal force F exerted upon the shoe 34 becomes smaller for a smaller weight of the shoe 34, and correspondingly, the moment M which causes the inclination of the shoe 34 becomes smaller. Similarly, the reaction force R becomes smaller and, thence, the angle of inclination O of the shoe 34 with respect to the sliding surface 40 becomes smaller. Accordingly, it is desired to minimize as much as possible the specific gravity of the shoe, and therefore, the base portion of the shoe according to the present invention is made of a high tensile aluminum alloy, titanium, or a high tensile titanium alloy, and it is desirable that the rate of use of the high load-bearing alloy as a bearing material will be minimized as much as possible. The best results may be obtained when the rate of use of the high load-bearing alloy, that is to say, the thickness thereof, is about 0.1 to 0.5 mm.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is to be understood, therefore, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A fluid pressure device of the axial plunger type comprising:

a housing;

a rotatable shaft within said housing;

a rotatable cylinder block operatively connected to said shaft and provided with a plurality of longitudinal cylindrical bores therein;

plungers slidably mounted, respectively, within said bores and including spherical outer end portions;

a valve plate located in abutment with an end surface of said cylinder block and having a pair of ports which communicate successively with said bores as said cylinder block rotates;

a swash plate pivotally supported upon said housing and having a slidable planar surface; and

a plurality of plunger shoes associated with said spherical outer end portions of said plungers at spherical socket portions thereof and including slidable bearing surfaces adapted for engaging said slidable planar surface of said swash plate for causing said plungers to reciprocate,

said shoes being formed of a light weight high tensile metal material and said slidable bearing surfaces of said shoes being formed of a high load-bearing alloy, wherein said high-load bearing alloy is applied to said slidable bearing surfaces of said shoe as a powder metallurgy material.

2. A fluid pressure device of the axial plunger type comprising:

a housing;

a rotatable shaft within said housing;

a rotatable cylinder block operatively connected to said shaft and provided with a plurality of longitudinal cylindrical bores therein;

plungers slidably mounted respectively, within said bores and including spherical outer end portions;

a valve plate located in abutment with an end surface of said cylinder block and having a pair of ports which communicate successively with said bores as said cylinder block rotates;

a swash plate pivotally supported upon said housing and having a slidable planar surface; and

a plurality of plunger shoes associated with said spherical outer end portions of said plungers at spherical socket portions thereof and including slidable bearing surfaces adapted for engaging said slidable planar surface of said swash plate for causing said plungers to reciprocate,

said shoes being formed of a light weight high tensile metal material and said slidable bearing surfaces of said shoes being formed of a high load-bearing alloy of aluminum and silicon.

3. A device as set forth in claim **2,** wherein said alloy of aluminum and silicon contains respective amounts of aluminum and silicon in the approximate porportion of 92–96: 4–8.

4. A device as set forth in claim **2,** where said slidable bearing surfaces of said shoes are made either of a copper alloy or a copper alloy of sintered material.

5. A device as set forth in claim **4,** wherein said copper alloy is either phosphor bronze or high-lead phosphor bronze.

6. A device as set forth in claim **5,** wherein a layer of molybdenum is provided between said copper alloy and said light weight high tensile metal material.

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