July 29, 1947. F. C. HOWARD 2,424,660

WOBBLE PLATE ENGINE

Filed May 7, 1945 2 Sheets-Sheet 1

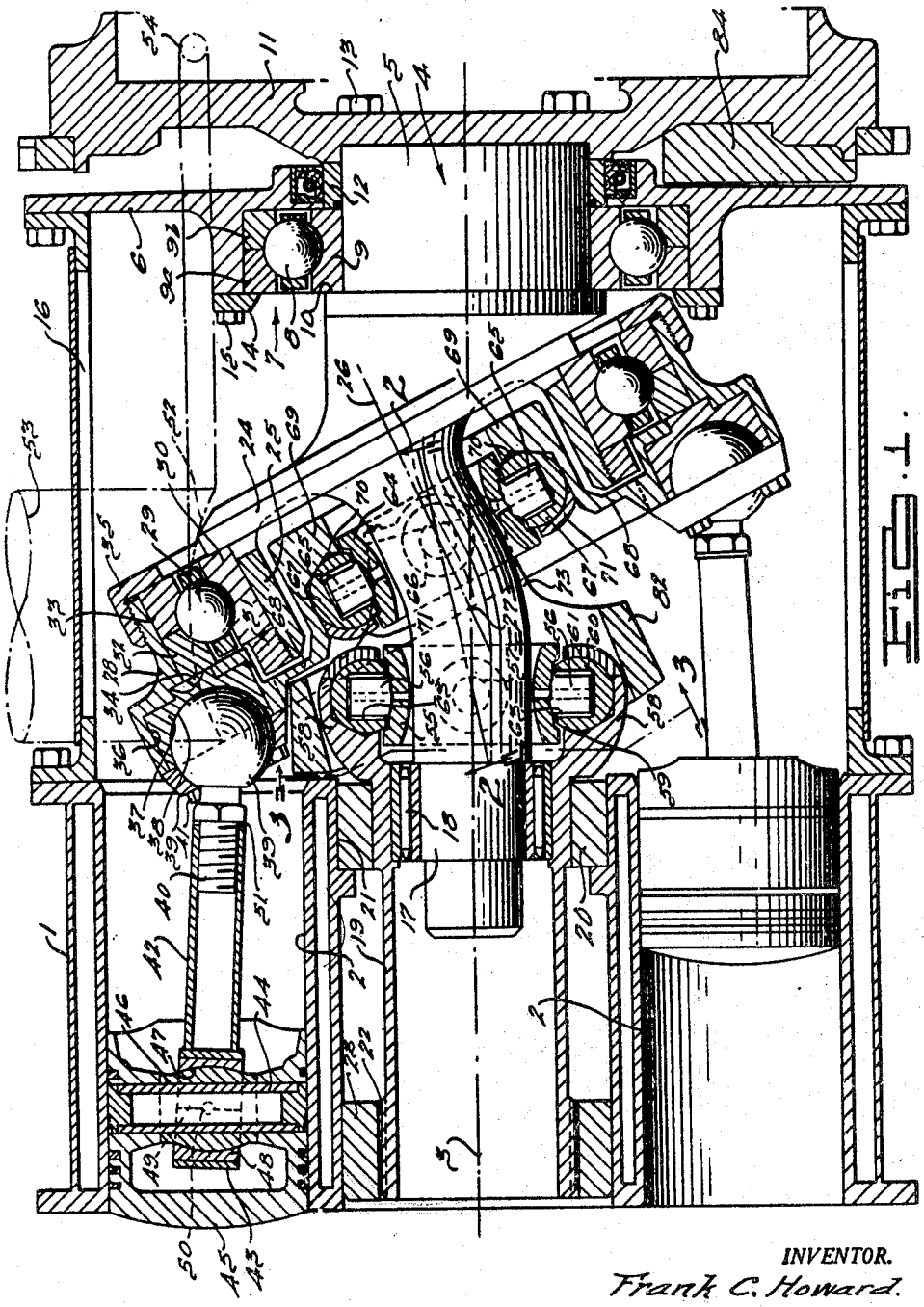


Fig. 1.

INVENTOR.
Frank C. Howard.
BY
Harness, Dickey & Pierce.
ATTORNEYS.

July 29, 1947. F. C. HOWARD 2,424,660

WOBBLE PLATE ENGINE

Filed May 7, 1945 2 Sheets-Sheet 2

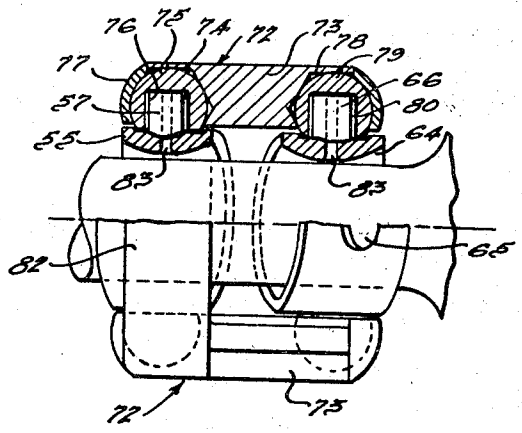


Fig. 2.

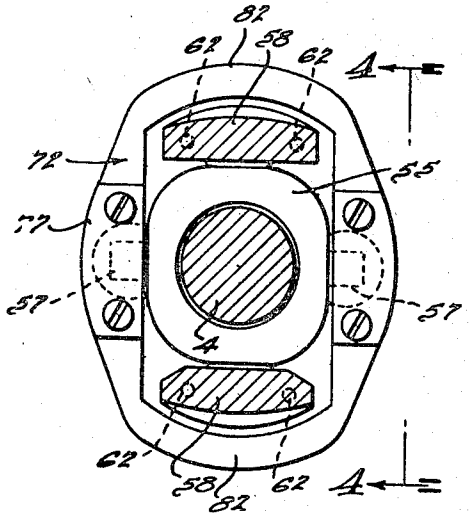


Fig. 3.

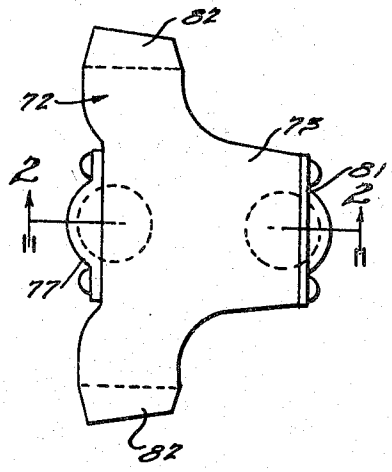


Fig. 4.

INVENTOR.
Frank C. Howard.
BY
Harness, Dickey & Pierce
ATTORNEYS.

Patented July 29, 1947 2,424,660

UNITED STATES PATENT OFFICE

2,424,660

WOBBLE PLATE ENGINE

Frank C. Howard, Dearborn, Mich.

Application May 7, 1945, Serial No. 592,346

20 Claims. (Cl. 74—60)

1

The present invention relates to a wobble plate engine of the type employing a circular ring of stationary parallel cylinders, a driven shaft concentric with and parallel to the cylinders, a wobble plate journaled on the shaft about an axis inclined to the shaft, and pistons in the cylinders operatively connected to the wobble plate at fixed points around its circumference.

It has long been recognized that, in theory, an engine of the above type has many advantages over crank type engines, but in spite of many prior efforts to design such an engine, none have met with practical success. It has also been known for many years that the primary defect in prior designs lay in the mechanism for controlling the motion of the wobble plate about its inclined axis. This mechanism must so connect the wobble plate to a stationary portion of the engine that any point on the wobble plate will trace a spherical lemniscate during each revolution of the shaft; and it must be sufficiently rugged to sustain the entire torque reaction of the engine. The recognition of the failure to solve this problem has led workers in the field to attempt to avoid it by employing designs which do not impose the torque reaction on the wobble plate (S. A. E. Journal, Transactions, vol 47, No. 6, December 1940; and U. S. Patent No. 2,303,838). These have greatly complicated the engine and have not proved practical.

Accordingly, it is the object of the present invention to provide a wobble plate engine of the type mentioned which incorporates an exceedingly simple, compact, and practical means to prevent rotation of the wobble plate about its own axis and to sustain the torque reaction of the engine.

Another object of the present invention is to provide mechanism of the type mentioned in combination with a wobble plate shaft coaxial with the cylinder block and journaled at both sides of the wobble plate.

Another object of the invention is to provide an improved type of wobble plate and mounting therefor.

Other objects and advantages of the invention will become apparent from the following specification, the accompanying drawings, and the appended claims.

In the drawings,

Figure 1 is a longitudinal sectional view of a preferred form of the invention;

Figure 2 is a fragmentary view of a portion of the mechanism, partially in section, on the line 2—2 of Figure 1;

2

Figure 3 is a sectional view taken generally on the line 3—3 of Figure 1.

Figure 4 is an elevation view taken on the line 4—4 of Figure 3.

The drawings illustrate only those portions of an internal combustion engine to which the invention ralates, and, consequently, do not show the cylinder head or valve mechanism, etc., but simply the cylinder block, the pistons, and the mechanism by means of which the pistons actuate the engine shaft. Thus, in Figure 1, is shown an illustrative form of the engine comprising a cylinder block 1 which constitutes a stationary portion of the engine and which is provided with a plurality of cylinder bores 2. While only two of the cylinder bores appear in Figure 1, it is to be understood that any desired number of cylinder bores may be provided so long as they are arranged parallel to and in a circle about the axis 3 of the engine shaft 4, which is the driven element of the engine. The particular engine illustrated has seven equally spaced cylinder bores of the same diameter. The enlarged right-hand end 5 of the engine shaft 4 is journaled within an end closure plate 6 by means of a ball bearing assembly, indicated generally at 7. While any desired form of combined radial and axial thrust bearing may be employed to journal the right-hand end of the shaft, the particular bearing illustrated comprises a ball bearing having a plurality of balls 8 which coact with an inner race 9 and a pair of outer races 9a and 9b. The inner race 9 is clamped against a shoulder 10 on the shaft by means of the flywheel 11 and a spacing sleeve 12, the flywheel being secured to the end of the shaft by a plurality of cap screws 13. The outer races 9a and 9b are clamped against the end closure plate 6 by means of a clamping ring 14, which is secured in position by means of a plurality of cap screws 15. The races 9, 9a, and 9b are so formed that each of the balls 8 makes a theoretical point contact with each of the races 9a and 9b at two spaced point contacts with the inner race 9. Consequently, the bearing will support the shaft against the end thrust as well as radial loads. The end closure plate 6 is fixed to the cylinder block 1 by means of a barrel 16.

The left-hand end of the engine shaft 4 has a reduced portion 17 which is journaled by means of a cylindrical needle bearing 18 within a sleeve 19. The sleeve 19 is slidably supported on a ring 20 fitted within a circular opening 21 formed in the cylinder block coaxial with the axis of the shaft. The left-hand end of the sleeve is provided with a splined section 22 having a sliding

spline connection with a ring 23 which is fixed in any suitable manner to the cylinder block.

A generally circular disk 24 having a cylindrical flange 25 is formed integrally with, or otherwise fixedly secured to, the shaft 4 in such manner that the axis 26 of the cylindrical flange 25 extends at an angle to and intersects the axis 3 of the shaft 4 at the point indicated by the numeral 27. In the preferred embodiment of the invention illustrated, the angle between the axes 3 and 26 is approximately 26 degrees, and the cylindrical flange 25 is located entirely on one side of, but projects from, the disk 24 toward the point 27 of intersection between the axes 3 and 26. An annular wobble plate 28 is journaled by means of a ball bearing assembly 29, identical in construction and mode of operation to the previously mentioned bearing 7, upon the cylindrical flange 25. The inner race 30 of the bearing 29 is clamped against the disk 24 by means of a nut 31 which is threaded upon the extremity of the flange 25. The outer races 32 and 33 are clamped against an internal shoulder 34 formed in the wobble plate 28 by means of a clamping nut 35. As a result of this arrangement the wobble plate 28 is free to rotate with reference to the cylindrical flange 25 on the shaft 4 and thus remain stationary while shaft 4 rotates.

The left-hand face of the wobble plate 28, as viewed in Figure 1, is provided with a plurality of circular recesses 36, each having its axis extending parallel to the axis 26. One such recess is provided for each cylinder 2 in the cylinder block. In each recess 36 is fitted a cylindrical block 37 having a semispherical concave recess 38 adapted to receive the spherical end 39 formed on a threaded stem 40. The spherical end 39 is retained against displacement from the recess 38 by means of an annular cap 39 provided with an internal concave surface of annular configuration, the retaining cap 39 being secured by means of cap screws 41 to the left-hand face of the wobble plate 28.

The threaded stem 40 is threaded into the end of a tubular connecting rod 42, the opposite end of which is fixed in any suitable manner, as by welding, to a sleeve 43 by means of which the connecting rod is secured to the piston pin 44 of a piston 45, in such manner as to permit limited universal movement of the connecting rod with reference to the piston pin. This connection is effective by means of a sleeve 46 having an internal cylindrical opening journaled upon the pin 44 and having an external spherical surface 47 journaled within a corresponding spherical internal surface formed in a sleeve 48 which is fixed within the sleeve 43. The sleeve 48 is split in the plane of the dotted line 49 of Figure 1 so that it may be removed from the sleeve 46. A pin 50, indicated in dotted lines in Figure 1, is fixed to the sleeve 43 and is journaled within suitable openings formed in the sleeves 46 and 48 in order to keep the sleeve sections 48 from shifting axially with respect to the piston pin 44. The pin 50, however, permits oscillation of the connecting rod 42 and the sleeves 43 and 46 about the axis of the pin 50, which axis is at right angles to the axis of the piston pin 44. The connecting rod 42 is permitted to oscillate about the axis of piston pin 44 by reason of relative movement between the sleeve 46 and the piston pin. It will be noted that a spacing washer 51 is provided between a shoulder on the member 40 and the right-hand end of the tubular connecting rod 42. The compression ratio of the engine may be varied by substituting washers of different thicknesses in place of the washer 51.

From the above it will be apparent that an operative connection is provided between each piston and a fixed point on the wobble plate 28, such point being located at the center of the spherical ball 39. It will be further noted that the point of connection, namely, the center of ball 39, is located in the plane which is normal to the axis 26 and passes through the point 27 of intersection between the axes 3 and 26. The radial distance from the point 27 to the center of each ball 39 is such that when the ball 39 is in the midpoint of its stroke it will be located at the same distance above the axis of the cylinder 2 as it lies below the axis of the cylinder 2 when it is at either end of its stroke.

An important feature of the wobble plate construction so far described resides in the fact that the bearing 29, which supports the wobble plate, is located at substantially the same distance from the axis 3 of the shaft 4 as are the axes of the cylinders 2. As a matter of fact, the diameter of the bearing 29 is so chosen that that portion of the bearing which, at any given instance, is closest to the cylinder block is located substantially on the axis of the adjacent cylinder and is, therefore, in a position to sustain the direct in-line thrust of the piston at the time of explosion. This relieves the wobble plate bearing of all load multiplication, due to an application of the load to the wobble plate at a point spaced radially outwardly of the bearing at the time of explosion.

It is well known that, with a connection between the pistons and the wobble plate which is located in fixed position circumferentially with respect to the wobble plate, the forces applied to the wobble plate by the pistons will tend not only to rotate the shaft 4 but also to rotate the wobble plate 35 with respect to the axis of the cylinder block 1. Accordingly, it is essential in all engine constructions of this type to employ means to prevent rotation of the wobble plate. Such means must absorb the entire torque reaction of the engine and, consequently, is subject to exceedingly heavy loads of constantly varying intensity. Moreover, as is well known, to avoid destructive vibration at ordinary engine speeds, it is essential to so restrain the wobble plate against rotation as to insure that each point on the wobble plate in the plane containing the centers of balls 39 travels in a curved path which is known as a "spherical lemniscate," i. e., a figure 8 drawn on the surface of a sphere. This essential motion for the centers of the balls 39 is indicated in dotted lines in Figure 1. Thus, the lemniscate, as viewed from the side in Figure 1, appears as an arcuate line indicated by the dotted line 52. When viewed from above, the curve appears as a figure 8, as indicated in the dotted line 53 above Figure 2. When viewed from the end, the curve appears as a small circle, indicated at the right of Figure 1 by the numeral 54.

It has been known that if it were possible to connect the wobble plate to the cylinder block of the engine by means of a constant velocity universal joint, the wobble plate would be given the type of restraint required to produce the above described movement of the centers of the balls 39, but no one has succeeded in so restraining the wobble plate, due, in part, to the fact that no satisfactory constant velocity universal joint is available which would be effective under the heavy loads and at the relatively high angle required. Moreover, prior attempts to incorporate

a constant velocity joint connection between the wobble plate and the cylinder barrel have involved an attempt to locate the torque transmitting elements of the joint radially outwardly of the wobble plate, in which position they are subject to the exceedingly rapid and destructive oscillation of the periphery of the plate. No room is available within the circle of connecting rods for the use of a centrally located constant velocity joint, due to the fact that a constant velocity joint capable of carrying the required heavy torque reaction loads would have to be of substantial size, and it is essential in a wobble-plate engine to maintain the wobble plate at the smallest possible diameter, so that for a given piston stroke the angle of the wobble plate axis to the shaft axis may be as large as possible. Moreover, it is highly desirable to provide supporting bearings for the engine shaft on both sides of the wobble plate. Consequently, the shaft extensions materially reduce the amount of space available for use of any type of universal joint. A single Hooke's or ordinary trunnion universal joint will not provide the proper wobble plate restraint and will set up a destructive vibration at a frequency which is twice engine speed. The use of two ordinary universal joints so connected as to transmit constant velocity has been successful in pumps in which the piston operating disk is directly driven about its own axis and the cylinder barrel is likewise driven about an inclined axis. However, in such constructions no torque reaction or driving load is sustained by the universal joints, and there is no element corresponding to the engine shaft in a wobble plate engine which must pass through the same space occupied by the universal joints. The use of two universal joints so connected as to transmit constant velocity has also been suggested in pumps of the type employing tilting boxes to support the piston operating disk in a given plane. In such constructions the cylinder block is rotated by the shaft and the disk is connected by the two joints to the shaft. In such constructions, however, the problem is not critical because the shaft does not sustain any bending loads as the result of piston thrust, and consequently may be cut away to make room for one or both joints. Moreover, the operating requirements and conditions of hydraulic pumps and motors are much less severe than internal combustion engines.

In accordance with the preferred embodiment of the present invention the necessary restraint of the wobble plate is provided by a pair of four-trunnion universal joints located within the radius of the wobble plate and arranged to transmit a constant velocity if either were rotated. Actually, however, since neither joint is rotated they maintain the wobble plate against rotation about its own axis. These joints are specially constructed and arranged to sustain the heavy torque reaction incident to operation of the engine, and at the same time to occupy so little space as to require no enlargement of the circle in which the axes of the cylinder bores lie. Furthermore, these joints are so constructed that they do not interfere with an extension of the drive shaft on both sides of the wobble plate and thus permit a journal support for the shaft at both ends.

Referring to the drawings, it will be noted that the shaft 4 is somewhat reduced in diameter at the left-hand side of the disk 24 and makes a more or less gentle curve in the region of the intersection of the axes 3 and 26. The first

universal joint comprises a ring 55 surrounding the shaft 4 and provided with two pairs of aligned radially extending trunnions 56 and 57. The trunnions 56 are aligned with each other and extend at right angles to the aligned trunnions 57, the point of intersection of the two pairs of trunnions lying on the axis 3 of the shaft 4. The trunnions 56 are connected to the aforementioned sleeve 19 by self-aligning bearings. Thus, the sleeve 19 is provided with a pair of projecting arms 58 provided at their ends with recesses 59 which are generally cylindrical with their axes extending parallel to the axis 3 and which have conically shaped bottom walls. A spherical bearing member 60 is fitted within each recess 59 and is held in position by a retaining cap 61, which is secured in position on either side of the recess 59 by means of cap screws 62, the positions of which are indicated in dotted lines in Figure 3.

Antifriction needle rollers 63 are provided between the trunnions 56 and the walls of the internal bore in the spherical bearing members 60.

The second universal joint comprises a ring 64 similar to the ring 65, and the ring is provided with two pairs of aligned trunnions 65 and 66. The trunnions 65 are similarly journaled by antifriction needle rollers in spherical bearing members 67. The wobble plate 28 is provided with two radially inwardly projecting arms 68, the inner extremities of which lie on opposite sides of the axis 26 and have axial projections 69 which extend to the right, as viewed in Figure 1, into the space within the cylindrical flange 25. The projections 69 are provided with cylindrical openings 70 whose axes extend parallel to the axis 26 and which are similar to the recesses 59 in arms 58 except that their open ends are to the left. The open ends of the recesses 70 are closed and the spherical bearing member 67 held in position in the recesses by means of a pair of retaining caps 71 similar to the caps 61 in the left-hand universal joint.

The aligned trunnions 56 are so held by the arms 58, and the aligned trunnions 65 are so held by the projections 69, that the centers of the two joints lie in the axes 3 and 26, respectively, at equal distances from and on opposite sides of the point 27 of intersection between those axes.

In order to complete the torque transmitting connection between the two joints, the aligned trunnions 57 of the left-hand joint are connected to the aligned trunnions 66 of the right-hand joint by the means best shown in Figures 2, 3, and 4. The connecting member is in the form of a ring, indicated generally at 72, which has a pair of axially projecting parallel arms 73 located on opposite sides of the shaft 4. The left-hand face of the ring in the vicinity of each projection 73 is provided with a cylindrical recess 74, similar to the recesses 59 and 70, which recess is adapted to receive a spherical bearing member 75 containing a plurality of antifriction needle rollers 76 and constituting bearings for the trunnions 57. A retaining cap 77, shown best in Figures 3 and 4, retains the spherical bearing member 75 in the recess and are identical in construction to the aforementioned bearing caps 61. The extremities of the projections 73 are provided with similar cylindrical recesses 78 which are aligned respectively with the recesses 74. The spherical bearing members 79 fitted within the recesses 78 contain needle rollers 80 which rotatably support the trunnions 66 of the right-hand joint. Retaining caps 81 retain the spherical bearing member 70 within the recesses 78. As a result of this

arrangement the aligned trunnions 57 are always held parallel to the trunnions 66 by the ring 72.

It will be observed that in accordance with the above described construction the two connected universal joints are so arranged that they will absorb the entire torque reaction of the engine and so restrain the movement of the wobble plate 28 that the point of connection between the wobble plate and connecting rod will travel in the path of the spherical lemniscate indicated by dotted lines in Figure 1, as is required to eliminate destructive vibration. The two universal joints are so constructed that they surround the drive shaft 4 and are free of contact therewith. Consequently, they permit the use of the outboard bearing 18 for the shaft and thus permit journaling of the shaft at both sides of the wobble plate. This greatly strengthens the wobble plate construction and reduces distortion of the drive shaft as well as the loads upon the drive shaft bearing.

Moreover, it will be noted that the construction of the universal joints and the connection between them is so arranged as to permit the use of a wobble plate of minimum diameter. In that connection it should be mentioned that the engine illustrated is a seven cylinder engine, and it would not be possible to have seven cylinders of equal size arranged with parallel axes in a circle about axis 3, if the diameter of that circle were any less than the distance between the axes of the cylinder bores 2, illustrated in Figure 1, without resulting in insufficient wall thickness between the respective cylinder bores of the cylinder block. Thus the engine illustrated is of minimum diameter for a seven cylinder engine having pistons of the diameter illustrated. The wobble plate is also closely coupled to the pistons. Nevertheless, the universal joints and the connection between them are so constructed that they will not interfere with any of the other mechanism. This is achieved in part by the peculiar construction of the ring 72 which forms the connecting member between the universal joints. This ring, instead of being located between the joints and surrounding the shaft 4, is located generally in the plane of a left-hand joint and is provided with generally arcuate portions 82 which surround the projecting arms 58 on the sleeve 19 and which connect the portions of the ring adjacent the projections 73. The cross-sectional form of the arcuate portions 82, as best shown in the upper part of Figure 1, is such that they will just clear the cylinder block 1, the projecting arms 58, and the wobble plate 28, including its inwardly projecting arm 68 and the retaining ring 39 when the position of that portion of the wobble plate opposite the annular ring portion 82 is closest to the cylinder block. The projections 73 of the ring 72 on the other hand are, as best shown in Figure 3, at a portion of the ring which is of a reduced diameter and, consequently, the projections 73 may extend into the interior of the cylindrical flange 25, intermediate the projections 68 on the wobble plate, and connect to the trunnions 66 without interference either with the cylindrical flange 25 or the shaft 4.

The universal joint trunnions are of necessity relatively small in size, and since they must carry the very heavy torque reaction while working at a substantial angle, their bearings will be subject to very high unit pressures, and it is for that reason that antifriction needle rollers are employed in the trunnion bearings. Moreover, due to the lack of space and the resulting high stresses which will be imposed upon the trunnions and the rings 55, 64, and 72, the joints and their connecting ring 72 will be subject to deformations under load beyond those ordinarily encountered in universal joint practice. Such deformations, however, are fully accommodated by the self-aligning spherical bearing members which may have a limited rotation within their recesses in response to any distortion which results under heavy loading, and thus remain in a position in which their central openings are parallel to the co-operating trunnion. This insures that the full load capacity of the bearing will be available at all times.

The previously described sliding connection between the sleeve 19, which carries the universal joint arms 58, and the cylinder block further operates to prevent excessive loading on the universal joint trunnion bearings which might otherwise result from distortion of the shaft 4 or the frame of the engine or unequal expansion of various parts of the engine due to the heat of the operation, since it permits a limited axial sliding of the left-hand universal joint along the axis 3 and thus eliminates endwise tension or compression forces on the universal joint assembly. The needle bearing 18 between the shaft 4 and the sleeve 19 permits limited relative sliding movement between the shaft and the sleeve for the same purpose.

The trunnion bearing may be lubricated in any desired manner as by splash or oil feeding systems, not shown, which will supply oil to openings 83 formed through each trunnion and the ring, of which it forms a part. Alternatively, if desired, the antifriction needle bearings may be filled with grease on assembly and a seal provided between the open end of each spherical bearing member and the base of the trunnion with which it is associated.

The engine may be substantially balanced against the inertia effects of the wobble plate by means of a counterweight 84, secured in the position illustrated in Figure 1, to the flywheel 11.

While only one form of the invention is illustrated and described it will be apparent that variations in the design of construction may be indulged in without departing from the spirit of the invention or the scope of the appended claims. Thus, the engine may have any desired number of cylinders and may, if desired, be provided with a second bank of cylinders at the right-hand side of the wobble plate, in accordance with the well-known principles. The detailed construction of the connecting rods and their connections to the pistons and wobble plate may likewise be altered as desired, so long as the point of connection between each connecting rod and the wobble plate is fixed against circumferential movement with respect to the wobble plate.

The mechanism of the present invention is peculiarly adapted for use in an internal combustion engine where high speeds and heavy loads are essential to commercially practical design. It will be appreciated, however, that the mechanism may also be used to advantage in high-speed hydraulic pumps and motors.

What is claimed is:

1. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journalled on said shaft on an axis inclined to and intersecting the shaft axis, means opera-

tively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, and means connecting said pairs of trunnions for maintaining them parallel to each other.

2. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journalled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, means surrounding said shaft and connecting said pairs of trunnions for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints.

3. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, a ring member for each joint, each said ring member surrounding the shaft and connecting the trunnions of its joint, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, and means connecting said pairs of trunnions for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints.

4. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, a ring member for each joint, each said ring member surrounding the shaft and connecting the trunnions of its joint, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, means surrounding said shaft and connecting said pairs of trunnions for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints.

5. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, and means connecting said pairs of trunnions for maintaining them parallel to each other, the connection between said first pair of trunnions and the stationary portion of the engine being adapted to permit movement of the center of the first joint along the axis of the shaft relative to the cylinder block.

6. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the

wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, means surrounding said shaft and connecting said pairs of trunnions for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints, the connection between said first pair of trunnions and the stationary portion of the engine being adapted to permit movement of the center of the first joint along the axis of the shaft relative to the cylinder block.

7. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, a ring member for each joint, each said ring member surrounding the shaft and connecting the trunnions of its joint, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, and means connecting said pairs of trunnions for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints, the connection between said first pair of trunnions and the stationary portion of the engine being adapted to permit movement of the center of the first joint along the axis of the shaft relative to the cylinder block.

8. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to and intersecting the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnions, means pivotally connecting said trunnions to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnions, a second universal joint having a pair of aligned trunnions, means pivotally connecting said trunnions of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnions, a ring member for each joint, each said ring member surrounding the shaft and connecting the trunnions of its joint, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, means surrounding said shaft and connecting said pairs of trunnions for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints, the connection between said first pair of trunnions and the stationary portion of the engine being adapted to permit movement of the center of the first joint along the axis of the shaft relative to the cylinder block.

9. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a four trunnion universal joint connected to a stationary portion of the mechanism with the center of the joint on the axis of said shaft, a second four trunnion universal joint connected to the wobble plate with its center on the axis of the wobble plate, the centers of said joints being located on opposite sides of and at equal distances from the point of intersection of said axes, and a member operatively connecting one pair of aligned trunnions of one of said joints with a parallel pair of aligned trunnions of the other joint.

10. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a four trunnion universal joint connected to a stationary portion of the mechanism with the center of the joint on the axis of said shaft, a second four trunnion universal joint connected to the wobble plate with its center on the axis of the wobble plate, the centers of said joints being located on opposite sides of and at equal distances from the point of intersection of said axes, bearings for said shaft on opposite sides of said universal joints, a ring member for each joint surrounding the shaft and connecting the trunnions of its joint, and a member surrounding the shaft and operatively connecting one pair of aligned trunnions of one of said joints with a parallel pair of aligned trunnions of the other joint.

11. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means oper-

atively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, and means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a four trunnion universal joint connected to a stationary portion of the mechanism with the center of the joint on the axis of said shaft, a second four trunnion universal joint connected to the wobble plate with its center on the axis of the wobble plate, the centers of said joints being located on opposite sides of and at equal distances from the point of intersection of said axes, and a member operatively connecting one pair of aligned trunnions of one of said joints with a parallel pair of aligned trunnions of the other joint, said member being in the form of a ring surrounding but not connected to the other pair of aligned trunnions of the first joint and having a pair of axial projections which provide bearings for the trunnions of the second joint.

12. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a four trunnion universal joint connected to a stationary portion of the mechanism with the center of the joint on the axis of said shaft, a second four trunnion universal joint connected to the wobble plate with its center on the axis of the wobble plate, the centers of said joints being located on opposite sides of and at equal distances from the point of intersection of said axes, bearings for said shaft on opposite sides of said universal joints, a ring member for each joint surrounding the shaft and connecting the trunnions of its joint, and a member surrounding the shaft and operatively connecting one pair of aligned trunnions of one of said joints with a parallel pair of aligned trunnions of the other joint, said member being in the form of a ring surrounding but not connected to the other pair of aligned trunnions of the first joint and having a pair of axial projections which provide bearings for the trunnions of the second joint.

13. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, the journal between the wobble plate and the shaft being a combined radial and axial thrust bearing having a radius substantially equal to the radius of the circle of the cylinder axes.

14. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, and means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, the journal between the wobble plate and the shaft being a combined radial and axial thrust bearing having a radius such that the portion of the bearing which is located closest to the shaft axis at any instant is spaced from the shaft axis by a distance substantially equal to the radius of the circle of the cylinder axes.

15. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, a generally cylindrical flange fixed to the shaft on an axis inclined to and intersecting the shaft axis and projecting toward the point of intersection of said axes, a wobble plate journaled on said flange, means operatively connecting the pistons to said wobble plate at points fixed circumferentially thereon, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a pair of universal joints connected together and connected respectively to the wobble plate and a stationary part of the mechanism, the centers of said joints being located respectively on the axis of the wobble plate and the axis of the shaft and being on opposite sides of and at equal distances from the point of intersection of said axes, and the joint which is connected to the wobble plate being positioned within said flange.

16. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, a generally cylindrical flange fixed to the shaft on an axis inclined to and intersecting the shaft axis and projecting toward the point of intersection of said axes and toward the cylinder block, said shaft having supporting bearings on opposite sides of said flange, a wobble plate journaled on said flange, means operatively connecting the pistons to said wobble plate at points fixed circumferentially thereon, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a pair of universal joints connected together and connected respectively to the wobble plate and to the cylinder block, the centers of said joints being located respectively on the axis of the wobble plate and the axis of the shaft and being on opposite sides of and at equal distances from the point of intersection of said axes, the joint which is connected to the wobble plate being positioned within said flange, each of said joints having trunnion bearings connected together by a ring surrounding said shaft, and the means connecting said joints being in the form of a ring surrounding said shaft.

17. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, a generally cylindrical flange fixed to the shaft on an axis inclined to and intersecting the shaft axis and projecting toward the point of intersection of said axes and toward the cylinder block, said shaft having supporting bearings on opposite sides of said flange, a wobble plate journaled on said flange, means operatively connecting the pistons to said wobble plate at points fixed circumferentially thereon, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a pair of universal joints connected together and connected respectively to the wobble plate and to the cylinder block, the centers of said joints being located respectively on the axis of the wobble plate and the

axis of the shaft and being on opposite sides of and at equal distances from the point of intersection of said axes, the joint which is connected to the wobble plate being positioned within said flange, each of said joints having self-aligning trunnion bearings connected together by a ring surrounding said shaft, and the means connecting said joints being in the form of a ring surrounding said shaft.

18. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnion bearings, means pivotally connecting said trunnion bearings to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnion bearings, a second universal joint having a pair of aligned trunnion bearings, means pivotally connecting said trunnion bearings of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnion bearings, each of said trunnion bearings being self-aligning to accommodate deflections under load, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, and means connecting said pairs of trunnion bearings for maintaining them parallel to each other.

19. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a universal joint having a member provided with a pair of aligned trunnion bearings, means pivotally connecting said trunnion bearings to a stationary portion of the mechanism on an axis perpendicular to the axis of said aligned trunnion bearings, a second universal joint having a pair of aligned trunnion bearings, means pivotally connecting said trunnion bearings of the second joint to the wobble plate on an axis perpendicular to the axis of said second pair of trunnion bearings, each of said trunnion bearings being self-aligning to accommodate deflections under load, a ring member for each joint surrounding the shaft and connecting the trunnion bearings of its joint, the centers of said joints being located respectively on the axis of the shaft and the axis of the wobble plate on opposite sides of and at equal distances from the intersection of said axes, and means surrounding said shaft and connecting said pairs of trunnion bearings for maintaining them parallel to each other, and bearings for said shaft on opposite sides of said universal joints.

20. A wobble plate mechanism comprising a stationary cylinder block having a plurality of parallel cylinders arranged in a circle, pistons in the cylinders, a rotary shaft parallel to said cylinders and coaxial with said circle, an annular wobble plate journaled on said shaft on an axis inclined to the shaft axis, means operatively connecting the pistons to the wobble plate at points fixed circumferentially on the wobble plate, and means for absorbing the torque reaction on the wobble plate and restraining its movement comprising a four trunnion universal joint connected to a stationary portion of the mechanism with the center of the joint on the axis of said shaft, a second four trunnion universal joint connected to the wobble plate with its center on the axis of the wobble plate, each of said trunnion bearings being self-aligning to accommodate deflections under load, the centers of said joints being located on opposite sides of and at equal distances from the point of intersection of said axes, and a member operatively connecting one pair of aligned trunnion bearings of one of said joints with a parallel pair of aligned trunnion bearings of the other joint.

FRANK C. HOWARD.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,139,450	Underwood	May 11, 1915
1,194,258	Walker	Aug. 8, 1916
1,612,925	Ingoldby	Jan. 4, 1927
1,659,374	Robson	Feb. 14, 1928
1,781,131	Shaff	Nov. 11, 1930