A hydrostatic pump-motor unit (35) including a clutch assembly (43) and a pump-motor portion (45) disposed within a housing assembly (51,55,57). An intermediate drive shaft (21) extends through the entire axial extent of the unit (35) and is surrounded by a hollow shaft member (63). The housing assembly (51,55,57) supports the drive shaft (21) by means of a pair of bearing sets (67,71), and the hollow shaft member (63) is supported relative to the housing assembly by means of a pair of bearing sets (75,79). The pump-motor portion (45) includes an axial piston cylinder barrel (115) surrounding the shaft member (63) and splined thereto. The clutch assembly (43) is operable to selectively clutch and de-clutch the drive shaft (21) and the hollow shaft member (63). Having the drive line extend through the pump-motor unit (35) substantially improves the packaging of the overall drive system.
AXIAL PISTON PUMP/MOTOR WITH CLUTCH AND THROUGH SHAFT

BACKGROUND OF THE DISCLOSURE

[0001] The present invention relates to a hydrostatic pump-motor unit, and more particularly, to such a unit which is intended for use in a vehicle drive system which also includes a mechanical transmission and drive line. As used herein, the term “drive line” will be understood to mean and include, but not be limited to, a conventional rear wheel drive type of prop shaft.

[0002] The hydrostatic pump-motor unit of the present invention may be used in connection with a variety of vehicle drive systems, but it is especially adapted for use in a vehicle drive system of the type in which torque is transmitted to the drive wheels from a mechanical transmission during part of the operating cycle, and from the hydrostatic unit during the remainder of the operating cycle, and the invention will be described in connection with such a system. It should be understood that for purposes of the present invention, the vehicle drive system may involve the transmission of torque from the hydrostatic unit to the drive wheels in lieu of torque from the mechanical transmission, or in addition to such torque.

[0003] More specifically, the present invention is especially advantageous when utilized as part of a vehicle drive system having regenerative braking capability, although it should be clearly understood that the present invention is not so limited. In such a system, and assuming by way of example only that the vehicle is of the rear wheel drive type, the primary drive torque is transmitted from the engine through the conventional mechanical transmission and then by means of a conventional drive line to the rear drive wheels. During braking (i.e., at any time during a “deceleration-acceleration” cycle,) the braking energy is transmitted to the hydrostatic pump-motor unit, which is then acting as a pump, and charges a high pressure accumulator. When the vehicle is subsequently accelerated, the hydrostatic pump-motor unit operates in a motoring mode, and the high pressure stored in the accumulator is then communicated to the pump-motor unit, and its output torque is transmitted to the vehicle drive line.

[0004] It will be understood by those skilled in the art that there are several reasons why the present invention is especially suited for use in a drive system of the type described above which has regenerative braking capability. First, such a system typically includes not only the high pressure accumulator referred to, but also a low pressure accumulator, and the presence of these two accumulators adds substantial size to the overall drive system, thus making packaging of the system especially challenging.

[0005] Secondly, a hydrostatic pump-motor unit which is being used in a system of the type described above needs to include the capability of being selectively clutched to, or de-clutched from, the main vehicle drive line, which further complicates the packaging of the entire system.

BRIEF SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide an improved hydrostatic pump-motor unit for use in a vehicle drive system which overcomes the problems described above.

[0007] It is a more specific object of the present invention to provide such an improved pump-motor unit which makes it possible to substantially reduce the overall packaging size of the drive system, as well as the complexity of the drive system.

[0008] The above and other objects of the invention are accomplished by the provision of an improved hydrostatic pump-motor unit adapted for use on a vehicle having a drive system including an engine, a transmission, and a drive line operable to transmit driving torque from the transmission to a drive axle. The hydrostatic pump-motor unit defines a housing including a fluid inlet port and a fluid outlet port, the housing defining a pumping cavity and disposed therein, a rotatable cylinder barrel defining a plurality of generally axially oriented cylinders, and a piston disposed for a reciprocable movement in each cylinder. The unit includes a swashplate disposed adjacent the barrel and having the pistons in engagement with the swashplate as the cylinder barrel rotates.

[0009] The improved hydrostatic pump-motor unit is characterized by the unit having bearings adapted to fix the location of the housing relative to the drive line. A hollow, generally cylindrical shaft member is adapted to surround the drive line and is surrounded by, and non-rotatably fixed relative to, the cylinder barrel. A clutch assembly is disposed adjacent a first end of the shaft member and includes a first clutch member adapted to be fixed for rotation with the drive line and a second clutch member fixed for rotation with the shaft member. A clutch assembly has a first condition in which the first and second clutch members are out of driving engagement, and a second condition in which the first and second clutch members are in driving engagement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic view of a vehicle drive system of the type with which the pump-motor unit of the present invention is especially well suited.

[0011] FIG. 2 is an axial cross-section of one embodiment of the entire hydrostatic pump-motor unit of the present invention.

[0012] FIG. 3 is an enlarged, fragmentary axial cross-section similar to FIG. 2, showing primarily the clutch assembly of the present invention.

[0013] FIG. 4 is an enlarged, fragmentary axial cross-section showing only the pump-motor portion, and on a slightly smaller scale than FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0014] Referring now to the drawings, which are not intended to limit the invention, FIG. 1 illustrates a vehicle drive system of the type with which the present invention is especially well suited. The vehicle shown schematically in FIG. 1 has four drive wheels W, although it should be understood that the present invention is not limited to a vehicle having four wheel drive, but could also be used with a vehicle having only two wheel drive, and in that case, the two drive wheels could be either rear drive wheels or front drive wheels. Operably associated with each of the drive wheels W is a conventional type of wheel brake B, the
details of which form no part of the present invention, and the wheel brakes B will be referred to only briefly hereinafter.

[0015] The vehicle includes a vehicle drive system, generally designated 11, which includes a vehicle engine 13 and a transmission 15. It should be understood that the particular type of engine 13 and transmission 15 and the construction details thereof form no part of the present invention and therefore, will not be described further herein.

[0016] Extending rearward from the transmission 15 is a drive line, generally designated 17. In the subject embodiment and by way of example only, the drive line 17 includes a forward drive shaft 19, an intermediate drive shaft 21 (see FIG. 2), a rearward drive shaft 23, an inter wheel differential 25 and left and right rear axle shafts 27 and 29.

[0017] The drive system 11, in the subject embodiment, also includes left and right forward axle shafts 31 and 33, respectively. Referring still primarily to FIG. 1, in addition to the "mechanical" elements already described and which are fairly conventional, the drive system 11 also includes a hydrostatic pump-motor unit, generally designated 35, and disposed forwardly of the pump-motor unit 35 is a valve manifold 37. Attached to a forward portion of the valve manifold 37 is a low pressure accumulator 39, and attached to a rear portion of the valve manifold 37 is a high pressure accumulator 41. It should be understood that the valve manifold 37 and the accumulators 39 and 41 are not essential features of the present invention, and therefore, the construction details of each is not illustrated or described herein. Instead, the general function and operation of each will be described briefly, but only to the extent necessary to describe the several operating modes of the pump-motor unit 35 of the present invention.

[0018] Referring primarily to FIG. 2, the pump-motor unit 35 will be described in somewhat more detail now, and even greater detail in connection with the description of FIGS. 3 and 4. The pump-motor unit 35 includes a clutch assembly, generally designated 43 and a pump-motor portion, generally designated 45. In accordance with an important aspect of the invention, it may be seen that the intermediate drive shaft 21 extends completely through the hydrostatic pump-motor unit 35 and has, at its forward end, a universal joint coupling (only partially shown) 47 for connection to the forward drive shaft 19. Similarly, the intermediate drive shaft 21 has, at its rearward end, a universal joint coupling 49, for connection to the rearward drive shaft 23.

[0019] Referring still primarily to FIG. 2, the clutch assembly 43 includes a clutch housing 51 which is bolted to a forward flange 53 of a pump-motor housing 55. Bolted to the rearward surface of the housing 55 is a port housing 57 which defines an inlet port 59 and an outlet port 61. Typically, the inlet port 59 and outlet port 61 would both be plumbed to the valve manifold 37. Surrounding a major portion of the axial length of the intermediate drive shaft 21 is a hollow, generally cylindrical shaft member 63, having its inside diameter radially spaced apart from the outside diameter of the intermediate drive shaft 21.

[0020] In accordance with another important aspect of the invention, a forward portion 65 of the intermediate drive shaft 21 is rotatably supported, relative to the clutch housing 51, by means of a ball bearing set 67 while a rearward portion 69 of the intermediate drive shaft 21 is rotatably supported relative to the port housing 57 by means of a ball bearing set 71. The shaft hollow member 63 includes forward portility 73 which is rotatably supported relative to the pump-motor housing 55 by means of a ball bearing set 75, while a rearward portion 77 of the shaft member 63 is rotatably supported relative to the port housing 57 by means of a roller bearing set 79. It should be noted that all of the bearing sets 67, 71, 75 and 79 are shown only schematically in FIG. 2.

[0021] Referring now primarily to FIG. 3, the clutch assembly 43 will be described in some detail. Disposed within the clutch housing 51 is an enlarged, externally splined portion 81 of the intermediate drive shaft 21. Surrounding the portion 81 is a clutch pack, including a set of internally splined clutch disks 83, and interleaved with the disks 83 is a set of externally splined clutch disks 85, the clutch disks 85 being in splined engagement with a clutch cage 87. The clutch cage 87 surrounds the clutch pack, and includes a radially extending portion 89 which is in splined engagement at its inner periphery with a set of external splines 91 formed about the forward portion 73 of the shaft member 63. Thus, the clutch cage 87 is fixed to rotate with the shaft member 63. Disposed immediately adjacent the radially extending portion 89 is a reaction member 90, preferably fixed to the portion 89, the primary function of the reaction member 90 being to provide rigidity to the entire clutch cage 87 whenever the clutch pack is loaded axially (engaged).

[0022] Disposed immediately adjacent the clutch pack (clutch disks 83 and 85) is a clutch apply piston 93, and disposed forwardly (to the left in FIG. 3) of the piston 93 is a ball ramp actuator 95, including an input ramp plate 97, an output ramp plate 99, and a plurality of cam balls 101. As will be understood by those skilled in the art, the input ramp plate 97 has its axial position, relative to the intermediate drive shaft 21, fixed by some form of axial retention and bearing arrangement, generally designated 103, the details of which are not essential features of the invention.

[0023] Disposed radially outwardly of the ball ramp actuator 95 is an electromagnetics coil assembly, generally designated 105, the function of which is to receive an electrical input signal, such as from the vehicle microprocessor, and initiate actuation of the ball ramp actuator 95. This is accomplished by the coil assembly 105 generating an electromagnetics field which is intersected by the input ramp plate 97 such that, when the coil assembly 105 is energized, rotation of the input ramp plate 97 is retarded somewhat which, in turn, causes ramping of the cam balls 101 on the ramp surfaces defined by the ramp plates 97 and 99, thus causing the output ramp plate 99 to be forced rearward (to the right in FIG. 3). Such rearward movement of the output ramp plate 99 overcomes the bias, in a forward direction, caused by a spring member 107, so that the output ramp plate 99 biases the clutch apply piston 93 rearward to load the clutch disks 83, 85. When such loading is applied to the clutch disks 83, 85, the shaft member 63 will thereafter rotate at the same speed as the intermediate drive shaft 21. When there is no such loading on the clutch disks 83, 85, the shaft member 63 remains substantially stationary within the stationary pump-motor housing 55.

[0024] It should be understood by those skilled in the art that, although the clutch assembly 43 is illustrated as includ-
erring a friction disk and ball ramp actuator type of clutch assembly, the present invention is not so limited. For example, the clutch assembly could be friction discs electro-hydraulically actuated, or could comprise a mechanical dog clutch (and a synchronizer, if necessary) actuated electromechanically, or could be whatever other known type of clutch and actuator meets the particular size, cost and operating criteria for the particular vehicle drive line installation.

[0025] Referring now primarily to FIG. 4, the pump-motor portion 45 will be described in some detail, recognizing that the construction details of the pump-motor portion 45 are not, in general, essential features of the present invention. The pump-motor housing 55 defines an internal cavity 111. As was best seen in FIG. 2, the hollow shaft member 63 extends into and axially through the entire extent of the internal cavity 111. The shaft member 63 includes a set of external splines 113, and disposed about that region of the shaft member 63 is a cylinder barrel 115 which includes a set of internal splines 117 in splined engagement with the external splines 113. Thus, the cylinder barrel 115 is non-rotatable relative to the shaft member 63 but in accordance with a primary aspect of the present invention, the cylinder barrel 115 surrounds the shaft member 63, and therefore, also surrounds the intermediate drive shaft 21.

[0026] The cylinder barrel 115 defines a plurality of cylinder bores 119, and disposed for reciprocating motion within each cylinder bore 119 is a piston 121. Each piston 121 includes a generally spherical head 123 which is received within a piston shoe (or "slipper") 125. The piston shoes 125 are retained in contact with a swashplate 127 in a manner generally well known to those skilled in the art and which forms no part of the present invention. The swashplate 127 is shown in FIG. 4, by way of example only, as being of the "swash and cradle" type although, those skilled in the art will understand that the swashplate 127 could also be of the trunnion type. In the subject embodiment, as shown in FIG. 4, the swashplate 127 is shown in its neutral (zero displacement) position because the pump-motor portion 45 is of the variable displacement type although, within the scope of the present invention, it would be possible for the pump-motor portion 45 to be of the fixed displacement type.

[0027] Those skilled in the art of drive systems of the type shown in FIG. 1 will understand that for the pump-motor portion 45 to be used in that type of drive system, it would be preferred that the pump-motor portion be of the variable displacement type. However, the particular mechanism by which the displacement of the swashplate 127 may be varied, from the neutral position shown in FIG. 4 toward a maximum displacement position in either direction therefrom, is well known to those skilled in the art, does not form an essential part of the invention, and will not be described herein. It is believed to be sufficient for purposes of this specification to merely point out that the displacement of the swashplate 127 would typically be varied by means of a piston and servo-type arrangement, in response to variations in a control pressure, which would typically be communicated to the pump-motor portion 45 from the valve manifold 37.

[0028] At the rearward end of the cylinder barrel 115 is a valve plate 129 which defines a plurality of inlet and outlet ports 131, by means of which the cylinder bores 119 are in cyclical communication with the inlet port 59 and with the outlet port 61, in a manner well known to those skilled in the art.

[0029] Although the use of the pump-motor unit 35 of the present invention in the drive system 11 shown in FIG. 1 is not an essential feature of the invention, it will be described briefly hereinafter to explain further the structure, function, and some of the benefits of the present invention. During "normal" operation of the drive system, i.e., when the vehicle is travelling along the highway at a generally constant velocity, no signal is being transmitted to the electromagnetic coil assembly 105 which is capable of energizing the coil 105 which, therefore, is in its "OFF" condition. With the coil assembly 105 in its OFF condition, the ball ramp actuator 95 is in its centered, neutral condition, under the influence of the spring member 107, and the clutch apply piston 93 has no substantial axial load applied thereto. With no load on the apply piston 93, the clutch disks 83 and 85 are not loaded into engagement but instead are in a "disengaged" condition, such that no torque is being transmitted from the intermediate drive shaft 21 to the hollow shaft member 63. In this disengaged condition, the shaft member 63 and the cylinder barrel 115 are able to remain stationary within the pump-motor housing 55, and the swashplate 127 remains in its neutral position shown in FIG. 4.

[0030] In the disengaged condition described above, the drive system 11 operates in a conventional manner, i.e., drive torque from the engine 13 is transmitted by the transmission 15, and the drive line 17 to the inter-wheel differential 25, and from there, by means of the left and right rear axle shafts 27 and 29 to the rear drive wheels W. In this disengaged mode of operation, the drive system 11 operates in substantially the same manner as it would if the pump-motor unit 35, the valve manifold 37 and the accumulators 39 and 41 were not present.

[0031] When it is necessary for the vehicle to decelerate, and the operator begins to depress the vehicle brake pedal, the initial movement of the brake pedal (not shown herein) results in a signal being communicated to both the valve manifold 37 and to the coil assembly 105, such that two things occur. The first is that the coil assembly 105 is energized, causing ramp-up of the ball ramp actuator 95 and engagement of the clutch disks 83 and 85, in the manner described previously, such that the hollow shaft member 63 is now fixed to rotate with the intermediate drive shaft 21. The second result of the brake pedal being depressed is that a signal is received at the valve manifold 37 which then communicates an appropriate control pressure to vary the displacement of the swashplate 127, and preferably in the system shown, the angle and direction of displacement of the swashplate 127 would correspond generally to the amount of braking "effort" applied by the vehicle operator.

[0032] As a result of the above-described "engagement" operation, the pump-motor portion 45 is now being driven by the drive line 17 and is acting as a pump, such that high pressure fluid is pumped out of the outlet port 61 to the valve manifold 37 and from there to the high pressure accumulator 41, such that the kinetic energy of the moving vehicle is converted to hydraulic energy, and is "stored" within the accumulator 41, as the vehicle gradually comes to a stop. Depending upon the amount of braking effort exerted by the
vehicle operator, the individual wheel brakes B may also be utilized in bringing the vehicle to a complete stop, although it is probably desirable in such systems to size the pump-motor unit 35 and high pressure accumulator 41 such that all normal braking operations are performed using only the hydraulic system, and the wheel brakes B are needed only in the case of an emergency.

[0033] When it is subsequently desired to accelerate the vehicle from a stop, such as by the operator depressing the accelerator pedal, an appropriate signal is communicated to the hydrostatic pump motor unit 35, and specifically, to the valve manifold 37. As a result of the signal indicating a need for vehicle acceleration, the valve manifold 37 communicates a control pressure to move the swashplate 127 “over-center” to an appropriate displacement in which the pump-motor portion 45 will now operate as a motor. In the “motoring” mode of operation, the valve manifold 37 will permit the high pressure fluid stored in the accumulator 41 to flow from the accumulator 41 through the valve manifold 37 to the inlet port 59, and from there into the cylinder bores 119. With pressurized fluid in the bores 119, the cylinder barrel 115 is now being driven and that drive torque is transmitted to the shaft member 63, and from there through the clutch disks 83 and 85 to the drive line 17, and specifically, to the intermediate drive shaft 21.

[0034] Thus, it may be seen that the novel arrangement of the intermediate shaft 21 and the pump-motor unit 35, in accordance with the present invention, provides a greatly improved packaging of the drive system 11, compared to the arrangement which would result from the use of the known, prior art axial piston pump and clutch assembly.

[0035] The invention has been described in great detail in the foregoing specification, and it is believed that various alterations and modifications of the invention will become apparent to those skilled in the art from a reading and understanding of the specification. It is intended that all such alterations and modifications are included in the invention, insofar as they come within the scope of the appended claims.

What is claimed is:

1. A hydrostatic pump-motor unit adapted for use on a vehicle having a drive system including an engine, a transmission, and a drive-line operable to transmit driving torque from said transmission to a drive axle; said hydrostatic pump-motor unit including a housing defining a fluid inlet port and a fluid outlet port, said housing defining a pumping cavity and disposed therein, a rotatable cylinder barrel defining a plurality of generally axially oriented cylinders, and a piston disposed for reciprocable movement in each cylinder, and a swashplate disposed adjacent said barrel and having said pistons in engagement with said swashplate as said cylinder barrel rotates; characterized by:

(a) said hydrostatic pump-motor unit having bearings adapted to fix the location of said housing relative to said driveline;
(b) a hollow, generally cylindrical shaft member adapted to surround said driveline and being surrounded by and non-rotatably fixed relative to said cylinder barrel; and
(c) a clutch assembly disposed adjacent a first end of said shaft member and including a first clutch member adapted to be fixed for rotation with said driveline, and a second clutch member fixed for rotation with said shaft member, said clutch assembly having a first condition in which said first and second clutch members are out of driving engagement, and a second condition in which said first and second clutch members are in driving engagement.

2. A hydrostatic pump-motor unit as claimed in claim 1, characterized by said drive-line including an intermediate drive shaft extending axially through the entire axial extent of said hydrostatic pump-motor unit, and including a forward portion and a rearward portion, said pump-motor unit including said bearings fixing the location of said housing relative to said forward and rearward portions of said intermediate drive shaft.

3. A hydrostatic pump-motor unit as claimed in claim 2, characterized by said hollow shaft member includes a second end, and said pump-motor unit further includes bearings rotatably supporting said first and second ends of said hollow shaft member relative to said housing.

4. A hydrostatic pump-motor unit as claimed in claim 1, characterized by said first clutch member comprises a friction disk and said second clutch member comprises a friction disk, and said clutch assembly further comprises an electromechanical actuator operable to move said friction disks between engaged and disengaged conditions in response to changes in response to an electrical input signal.

5. A hydrostatic pump-motor unit as claimed in claim 1, characterized by said housing enclosing both said cylinder barrel and said clutch assembly.

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