HYDRAULIC-MACHINE SYSTEM WITH IDLING MODE

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Our present invention relates to a hydraulic-machine system and, more particularly, to hydraulic machines driven by fluid under pressure or capable of displacing fluids, as well as a method of operating such systems.

The term hydraulic machine, as used hereinafter, is intended to define a transducer capable of converting mechanical movement into hydraulic displacement (i.e., displacement of a hydraulic fluid under pressure) or of converting fluid pressure into mechanical movement. Hydrodynamic and hydrostatic devices of this character include hydraulic motors, pumps and servo systems which generally have at least one pair of relatively movable members, one of which is provided with a plurality of variable-working elements (e.g., radial vanes, pistons, slides, valve elements and the like) which bear upon the other of the pair of members, the latter member having a contour defining the stroke of the elements. In a hydraulic pump, for example, the vanes may form an impeller and co-operate with the contour to define compartments or chambers from which hydraulic fluid under pressure is displaced and into which further quantities of the hydraulic fluid are drawn as the two members are relatively shifted. Alternatively, the contour may constitute a cam adapted to operate the elements as pistons in, for example, a radial-piston pump or motor. In this case, the elements which determine the fluid displacement or, in the case of a motor, the extent of the relative displacement. Many other hydraulic machines are characterized by these three principal structural components. Machines of this type, however, usually require some extraneous force to urge the variable-stroke working cam or contour carried by the opposing member. In a rotary hydraulic machine, for example, the radial-pistons or vanes can be urged against the contour or cam at least in part by centrifugal force. In most cases, however, it has been found desirable to supplement the centrifugal force with some other pressure means, e.g., a resilient or spring means (i.e., coil spring, compression chamber or the like), or the force of a hydraulic fluid derived from some external source. In all cases, however, difficulties are encountered when it is desirable to operate the hydraulic machine with a so-called "idling" mode. These difficulties apparently arise from the fact that the frictional engagement of the working elements with the contour or cam reduces the efficiency of the hydraulic device and, in the case of a pump, acts as a drag upon the driving motor whereas, in the case of a hydraulic motor, the operation of the load occurs with reduced efficiency. It is, accordingly, common to provide between the hydraulic motor or pump and the load or driving element, respectively, a clutch which decouples the hydraulic machine from the mechanical device co-operating therewith. The mechanical device can thus operate at an idling speed without being retarded by the frictional effects of the variable-stroke working elements.

It is, therefore, an important object of the present invention to provide a hydraulic machine of the general class described which is capable of operating with an idling mode or condition without the disadvantages of earlier hydraulic systems.

Another object of this invention is to provide a method of operating a hydraulic machine having variable-stroke working elements in such manner as to prevent the hydraulic device from retarding or reducing the efficiency of any mechanical device with which it may be coupled.

Still another object of this invention is to provide a system incorporating a hydraulic machine of the character described which eliminates the need for a clutch mechanism or the like between the mechanical element and the hydraulic machine when the operational modes are to include an idling condition.

These objects and others which will become apparent hereinafter are attained, in accordance with the present invention, by providing, in a system having a hydraulic machine wherein a pair of relatively movable members are respectively provided with a plurality of variable-stroke working elements and a cam or contour defining the stroke of the elements, means for hydraulically biasing the variable-stroke elements, in an idling condition of the machine, against those forces urging the elements in the direction of the contour or cam. The forces which are at least limitedly counteracted by the hydraulic bias just mentioned can derive from centrifugal force when, for example, one of the members is a rotor while the other is a stator, the rotor carrying the variable-stroke elements which bear upon an annular camming surface of the stator member. In the general case, i.e., where the movable member may or may not be a rotor, additional pressure means are provided during the normal operation of the device for holding the variable-stroke elements against the cam surface or contour end, according to the present invention, the means for hydraulically biasing these elements away from the contour are dimensioned to at least limitedly counteract the forces applied by such pressure means. The latter can be resilient means (e.g., coil springs, chambers containing a compressible fluid) or they may involve the use of a hydraulic force when, for example, the variable-stroke elements form pistons reciprocable within variable-capacity compartments. Such compartments can be fed with hydraulic fluid under pressure during the normal operating mode of the machine, the hydraulic fluid then serving to supplement a resilient means or the centrifugal action of the movable member. Thus, the method of the present invention involves the additional step of hydraulically biasing the variable-stroke working elements away from the contour in an idling condition of the machine, thereby reducing frictional interengagement of the members during this idling condition or mode. During the periods of normal machine operation, a hydraulic fluid may be supplied to the elements to urge them into contact with the contour, the latter hydraulic pressure being terminated when the idling condition is supplied for reducing the frictional interengagement.

According to a more specific feature of the present invention, the two members define between them at least one fluid chamber in which the working elements bear upon the contour, these elements having, exposed to fluid within this chamber, surfaces generally transverse to the direction of stroke, i.e., transverse to the direction in which they are normally hydraulically, resiliently and/or centrifugally biased. Thus the means for urging the elements away from the contour can include a source of fluid pressure and control means (e.g. a multi-position or distributing valve) connecting the source of fluid pressure with this chamber so as to expose these surfaces to fluid in the idling condition of the machine whereby the elements are displaced away from the surface which they normally bear against. The present invention is thus applicable to hydraulic machines employing radial-piston
elements, radial vanes, valves, sliding partitions, and other devices movable inwardly and outwardly and disposed either upon the rotor or upon the stator. In all cases, the pressure supplied by the source adapted to bias the elements away from the contour must be so great that at least part and preferably all of the force tending to urge them into contact with the contour is counterbalanced, and, even more advantageously, is sufficient to displace the elements from any contact whatsoever with the contour.

When the hydraulic machine is a radial-vane hydraulic motor (e.g. hydrostatic motor), it has been found desirable to provide a dual-pump means for displacing the hydraulic fluid to the machine. The dual-pump means can include a low-capacity pump constituting the source of fluid pressure designed to urge the variable-stroke elements away from the contour, and a high-capacity pump communicating with both the compartments in which the radial vanes or elements are shiftable as pistons and the compartments defined between the radial vanes and the relatively rotatable motor members. The control means can thus be a two-position valve which, in a first or normal position, connects the high-capacity pump with both the working compartments and the variable-capacity compartments or cylinders, whereas, in a second operative position (idling condition) the output of the high-capacity pump is returned to a reservoir. In this second position, the output of the low-capacity pump feeds only those working compartments which, in this case, constitute the fluid chamber in which the surfaces of the working elements are exposed to the fluid. A check-valve means is preferably interposed between the low-capacity pump and the high-capacity pump, these means being oriented to prevent the flow under pressure from the low-pressure pump to the reservoir in the second operative position of the control means.

Moreover, in this second operative position, the control means, is, according to a still more specific feature of the invention, so designed as to divert hydraulic fluid from the variable-capacity compartments or cylinders to a reservoir from which the dual-pump means draws hydraulic fluid. The control means can include a manually-operable two-position valve, or one which is responsive to fluid pressure in this system, to the rotational speed of the mechanical device or the hydraulic machine, or some still more remote means to which the system is to respond. Since the hydraulic pump is the kinematic reversal of a hydraulic motor, when the present invention is applied to such a pump, the discharge side or outlet of the rotary-vane machine must be blocked while the intake or suction side is supplied with fluid under pressure from a suitable source, e.g. one of the hydrostatic pumps mentioned above.

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

FIG. 1 is an axial cross-sectional view, in idealized form, of a hydraulic motor, according to the present invention, the remainder of the hydraulic system being shown diagrammatically; and

FIG. 2 is a cross-sectional view taken along the line II—II of FIG. 1.

In FIGS. 1 and 2, there is illustrated a hydraulic machine which, for the purpose of this description, can be a rotary-piston or rotary-vane hydraulic motor having a housing 6 in which an annular flow-control plate 5 is received, this plate being provided with an annular inlet bore or passage 4 in communication with the inlet opening 4' of housing 6. A pair of annular seals 5', 5'', surrounding the axial flange 5a of control plate 5, prevent escape of fluid between them and the housing 6, the control plate being further provided with three kidney-shaped apertures 7 communicating between the annular passage 4 and the working chambers or compartments to be described hereinafter. Between the control plate 5 and the further control plate 11, provided with the outlet apertures 16 of kidney-shaped configuration, there is disposed an annular member 10 constituting a cam and formed with the contour 10' which defines the stroke of the radial vanes 8 carried by the rotor 9. The rotor 9 has an internally splined shaft 9' of a load 30 is received for rotatable entainment. The hub 9' is mounted in the bearings 31 which, in turn, are bracketed by seals 32, 33 to prevent the escape of fluid between the housing 6 and the rotor 9. Each of the radial vanes 8 is slightly guided in the rotor 9 and is biased by spiral leaves 12 against the contour surface 10' of the annular cam 10. In addition, each of the radial vanes 8 is slidably in a variable-capacity compartment 20 which, in the region of the kidney-shaped inlet apertures 7, register with similar apertures 14' of the control plate 5, apertures 14' being guided in fluid via a duct 14 and the fluid line 15. In the regions or apertures 16, the control plate 11 is provided with kidney-shaped outlet apertures 25' which remove fluid from compartment 20 and conduct it to the duct 25 with which hydraulic line 19 communicates. The control plate 11 is formed with an annular passage 17, similar to that shown at 4, communicating with the kidney-shaped apertures 16 and leading hydraulic fluid out of the motor via an outlet 17'. Seals 11' and 11'' serve to prevent the escape of hydraulic fluid between the axially extending flange 11a and the housing 6. Axially extending bolts 34 draw the bipartite housings 6, the control plates 5, 11 and the cam 10 together, the rotor 9 being disposed between the control plates.

The remainder of the hydraulic system includes a dual-pump means, generally designated 3, including a low-capacity hydrostatic pump 3b which supplies fluid via a line 2 to the inlet 4'. The output of the hydrostatic pump 3a, however, communicates with a two-position valve 22 of the control means which feeds the line 15' to which hydraulic line 15 is connected. A check valve 24 interconnects line 2 and line 15'. The dual-pump means 3 is supplied with hydraulic fluid from a reservoir 23 to which the valve 22 returns hydraulic fluid via the line 23' when the valve connects this line with the return pipe 18. The fluid circuit is thus established between the pump means 3, the control valve 22, the inlet side of the hydraulic motor 1, the radial vanes and chambers defined thereby, the outlet side of the hydraulic motor 1, the return line 18, the valve 22 and the reservoir 23. In the second operative position of the valve 22, however, the hydraulic fluid large-capacity pump 3a is diverted to the reservoir 23 with which the hydraulic motor is connected as will become apparent hereinafter. The valve 22 may be controlled by the manual operating means diagrammatically represented at 35 or a tachometer 36 responsive to the rotary speed of the shaft 9' coupled with the load 30; a pressure-responsive device may also be provided for operating this valve.

In normal operation of the hydraulic motor 1 to drive the load 30, hydraulic fluid is drawn by both pumps 3a and 3b from the reservoir 23. The compressed fluid passes via the valve 22, in the indicated operative position, through line 15' and conduit 15 whence it enters the housing 6 and passes into duct 14 and thence through apertures 14' into the variable-capacity compartments 20 where it assists or supplements the springs 13 in the region of the radial vanes 8. In the region of the apertures 7, the hydraulic fluid enters the fluid chambers 14 formed by the rotor 7, the control plate 5, the further control plate 11 and the annular chamber defined against the cam 10. The flow-hydraulic fluid through line 2 is, however, at a low rate so that additional fluid passes via the check valve 24 to line 2 whence it enters inlet 4'. The hydraulic fluid entering duct 4 then proceeds through the working chambers or compartments 37 defined between the radial vanes 8, the rotor member 9 and the stator member 10. The rotor is thus driven in, for example, the counterclockwise sense as illustrated in FIG. 2 and, hydraulic fluid is discharged from the compartments 37.
through the outlet apertures 16, the duct 17 and outlet aperture 17', whence the fluid again proceeds via valve 22 to line 23' and the reservoir 23. The rotor 9 thereby drives load 30, the radial vanes 8 being shifted inwardly as they approach the regions between the interlaced apertures 7 and 16. In these regions, hydraulic pressure does not resist the movement of the vanes since their variable-capacity compartments 20 register with the kidney-shaped openings 25' and discharge fluid through duct 25 and line 19 past the check valve 21 into the return line 18. Check valve 26 remains blocked by the elevated pressure within line 15'. The use of three apertures 25', interlaced with the aperture 17', prevents the fluid under elevated pressure from being forced back through the control plate 5.

In the second operative position of the control valve 22, the output of the high-capacity pump 3a is returned to the reservoir 23 through 23' while line 15' likewise communicates with the reservoir. Line 16 is blocked by the valve 22. In this idling position of the valve, the auxiliary or low-capacity pump 3b supplies hydraulic fluid via line 2 to the inlet 4. The check valve 24 prevents transmission of fluid from line 2 to line 15'. The fluid entering duct 4 passes via apertures 7 into the working compartments 37 whence it bears upon the radial vanes 8 extending transversely to the direction of stroke (i.e., the stroke direction). The elevated fluid pressure in chamber 37 thus biases the radial vanes 8 inwardly and withdraws them from engagement with the cam 16, the pressure of low-capacity pump 3b being sufficient to counteract the force of springs 13 urging each of these radial vanes 8 outwardly. Since pump 3a no longer supplies fluid under pressure to line 15', the pressure within chambers 37 is sufficient to displace the radial vanes 8 and discharge the fluid within the variable-capacity compartments 20 through the ducts 14 and 25 to the lines 15 and 19, respectively. The fluid forces through duct 15 returns to the reservoir 23 via the valve 22 whereas that passing through line 19 cannot enter the blocked line 18 but flows past the check valve 26 into the line 15' which is now at reduced pressure. The hydraulic machine is now in an idling mode and can operate at the speed of the load 30 without significant frictional retardation of the latter. A relief valve 27 is provided to regulate the pressure within ducts 14 and 17 and within the compartments 37. When the pressure within these compartments exceeds that required to hold the radial vanes 8 out of engagement with the cam 16, the valve 27 opens to discharge fluid and restore the desired pressure. The invention described and illustrated is believed to admit of many modifications within the ability of persons skilled in the art, all such modifications being considered within the spirit and scope of the appended claims.

We claim:

1. In a method of operating a hydraulic machine wherein a pair of relatively movable members are provided respectively with a plurality of variable-stroke working elements entrained by one of said members and bearing upon the other of said members, said other member having a contour defining the stroke of said elements, the improvement which comprises the steps of: (a) supplying hydraulic fluid under pressure to said elements to urge them into contact with said contour and supplementing normal forces effective to maintain the elements in frictional engagement with said contour during normal operation of the machine and (b) hydraulically biasing said elements away from said contour in an idling condition of the machine against the forces urging the elements in the direction of the contour by supply fluid under pressure to said chambers while terminating the supply of fluid in step (a), thereby reducing frictional interengagement to said members during said idling condition.

3. A hydraulic system comprising a hydraulic machine having a pair of relatively movable members, a plurality of variable-stroke working elements entrained by one of said members and bearing upon the other of said members, said other of said members having a contour defining the stroke of said elements, and means including said elements and at least one of said members forming working compartments for a hydraulic fluid; and means for hydraulically biasing said elements in an idling condition of said machine against the forces urging the elements in the direction of said contour.

4. A system as defined in claim 3 wherein said members define between them at least one fluid chamber in which said elements bear upon said contour, said elements having in said chamber surfaces generally transverse to their direction of stroke, said means for hydraulically biasing said elements including a source of fluid pressure and control means connecting said source with said chamber in said idling condition of said machine.

5. A system as defined in claim 4 wherein said member entraining said elements is a rotor and said elements bear upon said other member with centrifugal force, said source and said control means being so dimensioned as to supply fluid pressure to said chamber in said idling conditions of said machine of a magnitude sufficient at least to balance part of the centrifugal force holding said elements against said contour.

6. A system as defined in claim 4 wherein said member entraining said elements is provided with pressure means urging said elements into contact with said contour under said forces, said source and said control means being so dimensioned as to supply fluid pressure to said chamber in said idling condition of said machine of a magnitude sufficient at least to balance part of said forces.

7. A system as defined in claim 6 wherein said pressure means includes source means urging said elements in the direction of said contour.

8. A system as defined in claim 6 wherein said pressure means includes variable-capacity compartments formed in the member entraining said elements and receiving same, and means for supplying hydraulic fluid under pressure to said variable-capacity compartments.

9. A system as defined in claim 8 wherein said means for hydraulically biasing said elements includes means for connecting said variable-capacity compartments to a fluid reservoir.

10. A system as defined in claim 8, further comprising dual-pump means for displacing a hydraulic fluid, said dual-pump means including a low-capacity pump constituting said source and a high-capacity pump communicating with both said working compartments and said variable-capacity compartments in one operative position of said control means wherein said hydraulic machine is in a normal operating condition and said fluid reservoir in a second operative position of said control means wherein said hydraulic machine is in said idling condition, said working compartment constituting said chamber; and check-valve means between said low-capacity pump and said high-capacity pump and oriented to prevent flow of fluid under said pressure pump to said reservoir in said second operative position of said control means.

11. A hydraulic system comprising a radial-vane hy-
drainage motor including a rotor, a plurality of radially shiftable vanes mounted on said rotor, spring means on said rotor urging said vanes radially outwardly, a stator surrounding said rotor and formed with an annular cam for regulating the stroke of said vanes and defining with said rotor and with said vanes a plurality of working chambers, inlet means for supplying hydraulic fluid under pressure to certain of said chambers, outlet means for removing hydraulic fluid from others of said chambers, said radial vanes each defining with said rotor a respective variable-capacity compartment, means for supplying fluid under pressure to said compartments, thereby urging said vanes into engagement with said cam in aiding relationship with said springs, means for leading fluid away from said compartments upon inward displacement of said vanes by said cam; dual-pump means including a relatively low-capacity pump and a relatively high-capacity pump; control-valve means interposed between said dual-pump means and said radial-vane motor and having a first position wherein said high-capacity pump communicates with said means for supplying hydraulic fluid to said compartments and said outlet means communicates with a reservoir, and a second position wherein said high-capacity pump communicates with said reservoir and said means for supplying fluid to said compartments communicates with said reservoir, said outlet means being blocked in said second position; check-valve means interconnecting said inlet means and said means for supplying fluid to said compartments in a sense permitting flow or fluid under pressure from said high-capacity pump to said inlet means in said first position of said control-valve means, said low-capacity pump communicating with said inlet means; and pressure-relief means communicating with said outlet means and effective in said second position of said control-valve means for regulating the pressure within said chambers generated by said low-capacity pump in said second position.