ABSTRACT

In a series hydraulic system involving a master hydraulic motor and a slave hydraulic motor in series, a pump means responsive to hydraulic pressure on the input side of the master hydraulic motor, is utilized to pump into that portion of the system between the master piston and the slave piston, a small amount of hydraulic fluid just sufficient to compensate for loss of volume in that portion of the system attributable to compressibility of the hydraulic fluid and expansibility of the associated system components.

5 Claims, 2 Drawing Figures
My invention relates to series hydraulic systems involving a master hydraulic motor and a slave hydraulic motor in series, and more particularly to such a system when employed in powering machines such as press brakes or the like, where accuracy is an important factor. The present invention, for purposes of disclosure, will be described in connection with its application to a press brake, though its utility is not restricted to such use only.

In the operation of hydraulically powered press brakes, the pressure developed in the hydraulic system during an operation on a piece of work, increases tremendously. Under the pressures thus created, the hydraulic liquid suffers a decrease in volume at the rate of approximately one-half percent per 1,000 pounds per square inch of pressure, while the physical structure of the system experiences some enlargement of the related components, attributable to expansion thereof under the pressures to which they are subjected. This offers no grave problem in hydraulic systems where the hydraulic motors are of like size and function in parallel.

In a series system, however, the hydraulic liquid in that portion of the system between the underside of the master piston and the top side of the slave piston, is confined or trapped. Where equal movements of the pistons is contemplated, as is usually the case with press brakes . . . etc., the area on the underside of the master piston must equal the area on the top side of the slave piston. If all other factors remain constant, then equal travel of the pistons may be expected.

During operation on a load however, the compressibility of the hydraulic liquid resulting from the high pressures developed in the system, insofar as it relates to the hydraulic liquid confined between the two pistons, is the equivalent of creating a small void in that portion of the system which must be taken up by the master piston moving slightly ahead of the slave piston, thereby causing a slight tilting of the ram of the press brake.

Also any expansion of the pertinent associated components of the system, due to such high pressures will have the same effect, and thus aggravate the situation, causing the master piston to advance still farther, until the required pressure build up is reached. Since such pressures are developed after engaging the work, inaccuracy in the work to be performed, may occur before any prevailing leveling system on the machine can function to level the ram.

Among the objects of the present invention are:

1. To provide a novel and improved hydraulic system involving hydraulic motors in series;

2. To provide a novel and improved hydraulic system involving a pair of hydraulic motors in series, said improved system including means for compensating for changes occurring in that portion of the system between the pistons of said motors, attributable to the development of heavy hydraulic pressures in the system;

3. To provide a novel and improved hydraulic system for a press brake or the like, wherein a master hydraulic motor and a slave hydraulic motor are connected in series to drive the ram of such a machine; and

4. To provide such a series hydraulic system for a press brake or the like, wherein changes in that portion of the system between the pistons of the hydraulic motors, attributable to high hydraulic pressures, will be compensated for.

Additional objects of my invention will be brought out in the following description of a preferred embodiment of the same, taken in conjunction with the accompanying drawings, wherein,

FIG. 1 depicts a basic series hydraulic system as applied to a press brake or the like, with the present invention incorporated therein, and FIG. 2 is a plot of volume versus pressure, which illustrates graphically how the compensating system of this invention functions.

For details of my invention in its preferred form, reference will be had to the accompanying drawing, wherein the basic series hydraulic system as shown, involves a master hydraulic motor 1 pivotally coupled to one end of the ram 3 of a machine such as the press brake, and a slave hydraulic motor 5 similarly connected to the opposite end of said ram. The ram is shown in the act of applying pressure to a deformable load 7 resting on a work table 9, a condition during which maximum pressure will be developed in the hydraulic system feeding such motors.

The hydraulic system under consideration basically involves hydraulically connecting such motors in series from a pump 11 driven by a motor 13, the pump deriving hydraulic liquid from a tank 15 to which liquid is discharged during movement of the ram. To provide such series connection, a flow line 17 extends from the discharge side of the pump to the upper end of the cylinder 19 of the master hydraulic motor to apply pressure to the master piston 20, the lower end of said master cylinder being connected by a line 21 to the upper end of the cylinder 23 of the slave hydraulic motor to apply pressure to the slave piston 24, and the circuit is completed by a flow connection 25 from the lower end of the slave cylinder, back to tank.

A three section solenoid controlled valve assembly 31 intercepts the pump discharge line and the return line. One section 33 of this valve assembly controls flow of hydraulic liquid to the upper ends of both cylinders, to produce a work stroke of the ram, while another section 35 reverses the flow in the system to bring about a return stroke of the ram, while the third section 37 will connect the pump directly to the tank, to enable idling of the machine.

A check valve 41 in the return line, is spring loaded sufficiently to support the ram in its uppermost position during idling or shut-down. Because of this, basic pressure will prevail in the hydraulic system just sufficient to effect this result.

In order to achieve an "up" or return stroke of the ram, the ram supporting check valve 41 in the return line, must be bypassed, and for this purpose, a check valve 43, spring loaded in the reverse direction, is connected across the ram support valve 41.

All of the foregoing is disclosed in the patent to Pearson et al. U.S. Pat. No. 3,143,924 of Aug. 11, 1964, for Control Means For Series Connected Cylinders Drive Assemblies.

The improvement to such system and which constitutes the essence of the present invention, involves the addition to such system of a means for compensating for changes occurring in that portion of the system between the pistons of the series connected hydraulic motors, attributable to the development of high load pres-
sures, and such compensation is accomplished by providing a pump means 47 responsive to such load pressures, for pumping into that portion of the system, just sufficient hydraulic liquid to overcome the effects of such changes.

Specifically, the pump means may take the form of a cylinder 49 with a piston 51 slidably installed therein, one end of the cylinder being connected to the input side of the master hydraulic motor 1 by a flow connection 53 while a flow connection 55 from the pump cylinder on the other side of the pump piston, terminates in that portion of the series system where compensation is to occur, namely, between the master piston and the slave piston. This in effect, places the compensating pump in parallel with the master hydraulic motor.

It is noted, however, that movement of the master piston 20 is resisted by the load 7 and must overcome such resistance in order that the machine may perform its operation on the load. Inasmuch as the piston 51 of the compensating pump, in the absence of other factors, would have no such resistance to overcome, it could deliver hydraulic fluid to that portion of the system between the motor pistons, at a pressure which might over compensate and cause the ram to tilt in the opposite direction.

It therefore becomes necessary to correspondingly balance the load on the pump piston to that on the master piston, to avoid overcompensation or undercompensation, and this is accomplished by causing the compensating pump piston 51 to operate against a load, such as would be provided by a spring 59 of selected calibration. To install such load, the compensating pump piston is provided with a piston rod 61 extending through the discharge end of the cylinder 49 where it supports a disc 63, and the load spring is installed between this disc, and backing plate 65 supported in spaced relationship to the end of the pump cylinder, whereby as the pump piston moves forward, the spring will compress and place a load thereon.

With a spring of proper calibration installed, the compensating pump will pump just sufficient hydraulic liquid into the related portion of the series hydraulic system, to compensate for compressibility of the liquid therein and expansion of the associated system components.

The operating characteristics of the invention are pictorially illustrated in FIG. 2 of the drawings, wherein the X-axis is calibrated in pounds per square inch and the Y-axis in terms of volume.

If the effective volume change, due to increasing load, followed a curve 67, then if the system 47 including the compensating means, is adjusted to supply hydraulic liquid along a curve 69, the deficiency in oil in the line 21 and associated portions of the hydraulic cylinders 19 and 23, attributable to compressive forces and pipe and joint expansions, then a resulting condition will follow whereby, in the absence of other possible disturbing forces, the attitude of the ram will not be upset. The machine will function as if the volume of liquid in the connecting line 21 and associated portions of cylinders 19 and 23 remained fixed, as represented by the dash line 71.

Should and slight deviations occur from other causes, with varying load on the machine, these will be readily taken care of by the leveling system with which such machines are conventionally provided. In any event, the correction which the conventional leveling system will be called up to correct for, will be minimized.

While I have illustrated and described my invention in its preferred form, it will be apparent that the same is subject to alteration and modification without departing from underlying principles involved, and I, accordingly, do not desire to be limited in my protection to the specific details illustrated and described, except as may be necessitated by the appended claims.

I claim:

1. In combination, a series hydraulic system including a master hydraulic motor and a slave hydraulic motor in series, and each involving a cylinder and included piston, the underside area of the master piston being equal to the topside area of the slave piston, and means, responsive to the development of pressure in the hydraulic fluid in said system, for compensating for compressibility of such hydraulic fluid in the system, connected to a passage between the underside of the master piston and the topside of the slave piston, said pressure responsive means also being connected directly to the input side of the master hydraulic motor and said passage of the series hydraulic system between the underside of the master piston and topside of the slave piston.

2. In combination, a series hydraulic system including a master hydraulic motor and a slave hydraulic motor in series, and each involving a cylinder and included piston, the underside area of the master piston being equal to the topside area of the slave piston, and means, responsive to the development of pressure in the hydraulic fluid in said system, for compensating for compressibility of such hydraulic fluid in the system, lying between the underside of the master piston and the topside of the slave piston, said pressure responsive means including a cylinder and piston slidably installed therein, a flow connection from the input side of said master hydraulic motor to said pressure responsive means cylinder to one side of its associated piston, and a flow connection from the opposite side of said pressure responsive means piston to a point in said series hydraulic system between the underside of the master piston and the topside of the slave piston.

3. A combination in accordance to claim 2, characterized by means, external to said series hydraulic system, for imposing resistance to movement of said pressure responsive means piston.

4. A combination in accordance with claim 4, characterized by said resistance imposing means including a piston rod extending from said pressure responsive means piston through an end of said pressure responsive means cylinder, and spring means bearing on said piston rod.

5. A hydraulic system comprising a master hydraulic motor and a slave hydraulic motor in series and including a communicating hydraulic passageway, each of said motors having a cylinder and included piston with the underside area of the master piston being the same as the topside area of the slave piston, means for compensating for the compressibility of hydraulic fluid in said communicating passageway, and for expansion of communicating passageway, said means including a cylinder-enclosed compensating piston hydraulically connected on one side to the high pressure side of said master hydraulic motor and on the other side to said communicating hydraulic passageway with resilient means exerting a predetermined force resisting movement of said compensating piston.

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