VARIABLE SPEED HYDRAULIC DRIVE SYSTEM

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ABSTRACT
The disclosure pertains to a crane drive system including a fluid crane motor for imparting horizontal motion and a fluid motor for actuating a hoist mechanism. A variable delivery pump drives the motors in a closed loop hydraulic circuit which includes control valves for starting and stopping the motors. Variable speed control of either or both motors is accomplished by varying the output of the pump.

9 Claims, 6 Drawing Figures
VARIABLE SPEED HYDRAULIC DRIVE SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates generally to hydraulic drive systems, and more specifically to a variable speed, closed loop hydraulic drive system for powering cranes and similar apparatus.

Conventional cranes employ an electric brake motor to impart horizontal motion and a second electric brake motor to actuate the hoist mechanism of the apparatus. The electric motor drives include starters, relays, etc. for regulating the operation of the motors, and brakes, limit switches, etc. are required for stopping the crane as desired.

Motorized crane apparatus of the type generally described present severe maintenance problems which result from repeated stopping and starting of the electric motors. The frequent stopping and starting of the electric motors is detrimental to their operation and causes motor failure. The brakes used to stop the crane require frequent adjusting and must be replaced periodically. The electro-mechanical starters and relays which are used to regulate the operation of the hoist motor are still another source of failure and require continual maintenance. All of these maintenance problems are particularly severe in modern automated crane systems because of the increased frequency of the start-stop cycles.

SUMMARY OF THE INVENTION

The present invention provides a closed loop hydraulic drive system which is used to power cranes or similar apparatus in place of the conventional electric brake motor drive arrangements. As will be apparent from the following description, the hydraulically driven crane apparatus of the invention eliminates the maintenance problems and other disadvantages associated with the electric motors, control circuitry and mechanical brakes of conventionally driven cranes.

The new crane drive system is characterized by a variable displacement pump which drives fixed, positive displacement fluid motors in a closed loop hydraulic circuit. Directional valves are included in the closed loop circuit for controlling the operation of the hydraulic motors which drive the crane horizontally and actuate the hoist mechanism. The variable delivery pump is driven by a continuously running electric motor. Since the pump motor runs continuously, it is not subject to the severe duty imposed by frequent start-stop cycles.

Variable speed control of both hydraulic motors is obtained by varying the displacement of the pump and thereby controlling the delivery of fluid to the motors. The fluid is delivered to the motors under pressure as required by the load and up to the maximum pressure setting of adjustable relief valves which are included in the closed loop hydraulic circuit. The maximum output torques of the fluid motors are controlled by pre-setting the relief valve pressures so that any overload will cause a stall and thus prevent damage to the crane apparatus.

Conventional mechanical brakes have been eliminated, and starting and stopping of the hydraulically driven crane apparatus is accomplished by controlling the output of the variable delivery pump and/or by operation of the directional control valves associated with the fluid motors. The low inertia of the rotating members in the hydraulic system assures smooth and fast starting, stopping and reversals of movement. Smooth starts from zero to any desired speed within the speed range of the fluid motors are obtained with gradual acceleration and deceleration.

The closed loop hydraulic circuitry which characterizes the new drive arrangement of this invention makes it ideally suited for operating cranes used in the plating industry to transport plating barrels between open tanks which contain electrolyte, rinsing solutions, and other liquid baths. Conventional open loop hydraulic circuits include a large, open reservoir from which a pump draws its fluid supply and into which the fluid is discharged. Such an arrangement cannot be used in the plating industry because of the danger of the plating solutions being contaminated by spillage from the reservoir during starting and stopping of the crane. In the drive arrangement of this invention, the fluid from the hydraulic motors is returned directly to the pump in a closed loop rather than to a separate reservoir. Consequently, the danger of contamination is not present.

Other advantages and a fuller understanding of the invention will be had from the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical elevational view, partially in cross-section, showing a plating line including a hydraulically driven crane apparatus according to the present invention;

FIG. 2 is a diagrammatical, top plan view of the apparatus shown in FIG. 1;

FIG. 3 is a diagrammatical, side elevational view with portions broken away of the apparatus shown in FIG. 1;

FIG. 4 is a fragmentary, enlarged view of a portion of the apparatus shown in FIG. 3;

FIG. 5 is a schematic of the hydraulic circuit embodied in the crane apparatus; and,

FIG. 6 shows electrical circuitry for controlling operation of the hydraulic drive system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, and to FIGS. 1–3 in particular, the present invention is shown as embodied in an overhead crane 10 which is movable along a runway formed by spaced rails 11, 12. The spaced rails 11, 12 may be supported in any suitable manner, as by horizontal beams 13 which are part of a structural framework that further includes vertical beams 14 connected at their upper ends by horizontal cross beams 15.

For purposes of describing the invention, the crane 10 is illustrated as being operable to carry a plating barrel 18 along a plating line for processing of the parts in the barrel at a series of stations. The plating line will be understood to be made up of a plurality of aligned, open tanks 19 which contain various liquid baths, such as water rinse baths, cleaner solutions, plating solutions, etc. In operation, the crane 10 is stopped at a desired station above a tank and the barrel 18 is lowered and rotated in the bath. After processing for a suitable length of time, the barrel is raised from the tank and the crane is moved along the runway formed by the rails 11, 12 to the next station where the operation is repeated.

As shown, the crane 10 is comprised of a support or frame 25 formed by suitable structural members, in-
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including beams 26 which define the ends of the frame and beams 27 which define the sides of the frame. Beams 28, 29 are secured to the opposite sides of the frame 25 and extend downwardly. Plates 30, 31 and a pair of channel members 32, 33 for supporting the crane drive system and reinforcing the frame 25 extend between and are secured to the end beams 26. The support or frame 25 is mounted for movement along the rails 11, 12 by two sets of wheels 35, 36 which are carried on the ends of shafts 37, 38, respectively. The shafts 37, 38 extend across the frame 25 and are journaled in bearings supported by the side beams 27. Sprockets 39 are fixed on the shafts 37, 38 and are connected by a chain 40.

The crane 10 also includes a chain hoist or lift for raising and lowering the barrel 18. The chain hoist or lift arrangement comprises a rotatable shaft 45 extending between the vertical beams 28, 29 of the crane, an upper pair of sprockets 46, 47 mounted on the shaft 45 near its ends, and a lower set of sprockets 48, 49 which are adjustably connected to the beams 28, 29 near their lower ends. The sprockets 46, 47 are connected by an endless chain 50, and the sprockets 47, 49 are connected by an endless chain 51. A lift bar 52 for supporting the barrel 18 has its ends connected to the chains 50, 51 so that the bar will be raised and lowered with movement of the chains.

The barrel 18 may be supported by the lift bar 52 in any suitable manner. In the illustrated arrangement, the barrel supporting structure is comprised of a frame 60 including a pair of depending legs 61 which serve to rotatably mount the barrel 18 at its ends. The frame 60 also includes a pair of hooks 62 which extend upwardly for engagement over the lift bar 52. The barrel 18 may be rotatably driven by means of a shaft 63 which is rotatably carried by the frame 60 and is operatively connected to the ends of the barrel 18 by a belt drive 64. The shaft 63 has a gear (not shown) at one end which is adapted to be engaged by cooperating gear drives (also not shown) mounted at the sides of the tanks 19 at each station. When the barrel is lowered into any of the tanks, the gear on the end of the shaft 63 is engaged with the gear drive at the side of the tank to rotate the barrel 18.

In accordance with the present invention, the crane 10 is reversibly driven along the rails 11, 12 by a fixed, positive displacement fluid motor 65, and the chain lift is actuated by a similar fluid motor 66. As shown in FIGS. 1 and 2, the crane fluid motor 65 is supported on the plate 30 of the frame 25 and is drivingly connected to the wheel shaft 38 by a chain 67 which is engaged around a sprocket on the fluid motor shaft 67 and a sprocket 68 on the wheel shaft. The lift motor 66 is coupled to a worm gear speed reducer unit 74 mounted on the plate 30 which drives a chain 75 engaged around a sprocket 76 on the shaft 45. The speed reducer 74 has a low lead angle, preferably 10 degrees or less, on the worm, whereby the unit will prevent the hoist load from falling.

The fluid motors 65, 66 are driven by a hydraulic drive unit 80 which is supported on the plate 31 of the crane frame 25. As will be explained in greater detail, the output speed of both motors is regulated by controlling the supply of hydraulic fluid from the unit 80. To this end, the unit 80 includes an external control arm 81 which is best shown in FIG. 4. The control arm 81 may be selectively positioned by actuation of a piston-cylinder unit 82 to vary the delivery of fluid from the unit 80. The piston-cylinder unit 82 is pivotally mounted on one of the beams 26 by a bracket 83 and a clevis 84. The piston rod 85 of the unit 82 is connected by a clevis 86 to the control arm 81. The speed regulating, piston-cylinder unit 82 is actuated by fluid supplied from the drive unit 80 through a solenoid-operated, directional valve 87 mounted on the channel member 33 of the crane frame 25.

Starting and stopping of the motors 65, 66 may be selectively controlled by solenoid-operated directional valves 90, 91, respectively, which are in circuit relation between the motors and the drive unit 80. As shown in FIG. 2, the valves 90, 91 are supported on the channel member 32 of the crane frame 25.

Reference is now made to FIG. 5 which is a schematic of the drive unit 80 and of the closed loop hydraulic circuit including the drive unit, the motors 65, 66, the piston-cylinder unit 82, and the associated directional valves. For purposes of clarity, the external system lines of the hydraulic circuit which connect the motors, control valves, etc. have not been shown in FIGS. 1–3.

The drive unit 80 is a commercially available, self-contained unit consisting of a pump motor 95 and an integral hydraulic circuit enclosed within a housing which is represented by the broken line 96. The integral hydraulic circuit of the unit 80 comprises a variable delivery piston pump 97 which is driven by the motor 95 and which is ported to housing passages 98, 99. Cross-line adjustable relief valves 100, 101 are provided between the passages 98, 99, and a drain line 102 connects the pump 97 to a reservoir 103 within the housing 96.

The fluid motors 65, 66 are in series connection with the pressure passages 98, 99 of the drive unit 80. Each of the motor control, solenoid-operated valves 90, 91 is a three-position, four-way directional valve. The pressure passage 98 of the drive unit 80 is connected to a port of the motor control valve 90 by a system line 110, and the pressure passage 99 is connected to a port of the motor control valve 91 by a system line 111. The valves are connected by a system line 112 so that, when the valves are in their illustrated center positions, fluid supplied from the pump 97 through the pressure passage 98 will flow through the valves and return to the pump through the other pressure passage 99. The cylinder ports of the valve 90 are connected to the motor 65 by system lines 113, 114 so that the motor can be driven in either direction by selective energization of the valve solenoids 90A, 90B to actuate the valve between its two operative positions. The cylinder ports of the valve 91 are similarly connected to the motor 66 by system lines 115, 116 so that the motor can be driven in opposite directions by selectively energizing the valve solenoids 91A, 91B to actuate the valve between its two operative positions. As shown, the motors 65, 66 are respectively provided with drain lines 120, 121 which are connected by passage 122 in the housing 96 to the housing reservoir 103.

When the solenoid 90A is energized, the valve 90 is operated to connect the system line 110 to line 113 and the system line 114 to the line 112. In this position of the valve, fluid from the pump 97 is supplied to the crane motor 65 through the pressure passage 98 and the connected lines 110, 113. The fluid is returned to the pump in a closed loop through the connected lines
114, 112, the valve 91, the line 111 and the pressure passage 99. Energization of the solenoid 90B is effective to reverse the crane motor 65 by connecting the pressure line 110 to the line 114. In this position of the valve 90, the fluid is returned to the pump in a closed loop via the connected lines 113, 112, the valve 91, the line 111 and the passage 99.

When the solenoid 91A is energized, fluid from the pump 97 is supplied to the hoist motor through the pressure passage 98, the line 110, the valve 90 and the connected lines 112, 115. The fluid returns to the pump in a closed loop via the connected lines 116, 111 and the passage 99. Energization of the solenoid 91B is effective to reverse the hoist motor 66 by connecting the pressure line 112 to the line 116. In this position of the valve 91, fluid returns to the pump 97 via the lines 115, 111 and the passage 99.

As will be apparent, the output torque of the motors 65, 66 can be controlled by setting the relief valves 100, 101 so that any overloads will result in a stall rather than damaging the crane 10. The fluid will be delivered to the motors 65, 66 as required by the load and up to the maximum pressure settings of the valves 100, 101.

The integral hydraulic circuit of the drive unit 80 further includes a replenishing pump 130 for making up fluid losses in the above-described fluid motor circuit and for maintaining a stable system pressure. The replenishing pump 130, which is driven by the electric motor 95, draws fluid from the reservoir 103 and is connected to the housing passages 98, 99 by an auxiliary circuit including a filter 131, and replenishing check valves 132, 133. The auxiliary circuit of the replenishing pump also includes a relief valve 134 connected between the output side of the pump and the reservoir 103.

The replenishing pump 130 also supplies fluid for actuation of the speed regulating, piston-cylinder unit 82. As shown, the pressure side of the pump is communicated to the solenoid-operated valve 87 by an external system line 140. An external exhaust line 141 connects the valve 87 to a housing passage 142 which communicates with the replenishing pump reservoir 103. The valve 87 is a three-position, four-way directional valve which is connected to opposite ends of the piston-cylinder unit 82 by system lines 143, 144. Flow rate valves 145 and by-pass check valves 146 are provided in the lines 143-144.

Energization of the valve solenoids 87A, 87B to operate the valve 87 between its operative positions is effective to actuate the piston-cylinder unit 82 in opposite directions in order to selectively position the control arm 81. As generally explained above, movement of the arm 81 controls the fluid supplied from the variable delivery pump 97 and thereby regulates the output speed of the motors 65, 66. The position of the control arm 81 as shown in FIG. 5 is a zero speed position in which the supply of fluid to the motors 65, 66 is effectively shut-off. Energization of the solenoid 87 is effective to advance the piston-cylinder unit 82 by connecting the pressure line 140 to the line 144 and the line 143 to the exhaust line 141. This causes the control arm 81 to rotate counterclockwise as viewed in FIG. 5, whereby the output from the pump 97 is increased to the maximum. Energization of the solenoid 87B retracts the piston-cylinder unit 82 by connecting the pressure line 140 to the line 143 and the line 144 to the exhaust line 141. This causes the arm 81 to be returned toward the illustrated zero speed position. Control positioning of the arm 81 in the described manner is effective to infinitely vary the motor output speeds from zero to maximum rpm depending upon the torque load and the rated output of the motors 65, 66.

The control valves 87, 90, 91 may be remotely controlled through any suitable electrical control circuitry. By way of example, there is shown in FIG. 6 a simplified circuit including a motor stop switch 160 and a motor start switch 161. Actuation of the start switch 161 closes the motor relay 162 to start the pump motor 95. The motor 95 runs continuously during the entire period during which the crane 10 is in operation. A suitable selector switch 167 is provided for individually energizing the solenoids 90A, 90B of the valve 90. A second selector switch 168 is provided for selectively energizing the solenoids 91A, 91B of the valve 91. The control circuitry also includes a selector switch 169 for individually energizing the solenoids 87A, 87B of the valve 87.

Although not shown, the electrical control circuitry may further include proximity switches or limit switches in circuit relation with the solenoids 90A, 90B. The switches may be suitably mounted along the rails 11, 12 for decelerating and stopping the crane at each station. Similar switches may be mounted on the vertical crane beams 28, 29 in circuit relation with the solenoids 91A, 91B for stopping the chain lift in its up and down positions.

Briefly summarizing the operation of the crane drive system, the valve 90 is selectively actuated to operate the crane motor 65 in either a forward or reverse direction and thereby run the crane 10 along the rails 11, 12 to a station above a tank 19. The crane is stopped at the station by deenergizing the solenoid 90A or 90B so that the valve 90 is returned to its center position blocking fluid flow to the motor 65. Thereupon the valve 91 is actuated by energization of one of the solenoids 91A, 91B to actuate the hoist motor 66 and lower the barrel 18 into the tank. Subsequently, the valve 91 is operated to reverse the motor 66 and raise the barrel 18 out of the tank. The valve 90 may then be operated to start the crane motor 65 and cause the crane to be moved along the rails to the next position. The speed of the motors 65, 66 is controlled by positioning the arm 81 through actuation of the valve 87.

As will be seen from the foregoing, the invention has provided a novel hydraulic crane drive system characterized in part by closed loop circuitry, whereby fluid supplied to either of the motors 65, 66 is returned directly to the variable delivery pump 97 rather than to a reservoir. It will also be seen that the system permits fast starting and stopping, together with infinitely variable speed control. All of these advantages are obtained in a system which is not subject to the maintenance problems encountered with conventional electrically powered cranes.

Many variations and modifications of the invention will be apparent to those skilled in the art in the detailed disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically shown and described.

What is claimed is:
1. In an arrangement including a plurality of open tanks and a crane movable along a runway over said
tanks, the improvement wherein said crane comprises hoist support means engaged on said runway for movement along a path of travel above said open tanks, said support means being actuable through repeated cycles of acceleration, deceleration and stopping during movement along said runway to selected locations over said tanks; load hoist means carried by said support means for movement to said locations; frame means operatively connected to said hoist means and adapted to be raised and lowered by said hoist means when said support means is over a selected tank; an article container rotatably mounted on said frame means so that said container can be placed in and removed from a selected tank by raising and lowering said frame means; and a hydraulic drive system carried on said crane for actuating it through said cycles of acceleration, deceleration and stopping, said drive system including a first rotary fluid motor connected to said support means for powering it along said runway, a second rotary fluid motor connected to said hoist means for raising and lowering said container, a hydraulic drive unit including a variable delivery pump and first and second flow passages connected to said pump, and circuit means defining a closed loop fluid flow path connecting said motors in series to said first and second passages, said circuit means being characterized by the absence of a fluid-containing reservoir so that the fluid supplied by said pump to said motors is returned directly to said pump, and said circuit means including first and second directional valves between said pump and said first and second motors.

4. In an arrangement including a plurality of open tanks and a crane movable along a runway over said tanks, the improvement wherein said crane comprises hoist support means engaged on said runway for movement along a path of travel above said open tanks, said support means being actuable through repeated cycles of acceleration, deceleration and stopping during movement along said runway to selected locations over said tanks; load hoist means carried by said support means for movement to said locations; frame means operatively connected to said hoist means and adapted to be raised and lowered by said hoist means when said support means is over a selected tank; an article container rotatably mounted on said frame means so that said container can be placed in and removed from a selected tank by raising and lowering said frame means; and a hydraulic drive system carried on said crane for actuating it through said cycles of acceleration, deceleration and stopping, said drive system including a first rotary fluid motor connected to said support means for powering it along said runway, a second rotary fluid motor connected to said hoist means for raising and lowering said container, a hydraulic drive unit including a variable delivery pump and first and second flow passages connected to said pump, and circuit means defining a closed loop fluid flow path connecting said motors in series to said first and second passages, said circuit means being characterized by the absence of a fluid-containing reservoir so that the fluid supplied by said pump to said motors is returned directly to said pump, and said circuit means including first and second directional valves between said pump and said first and second motors.
6. Apparatus as claimed in claim 2 wherein said pump means is a variable delivery pump, and including control means connected to said pump for controlling the fluid output and thereby regulating the speed of said motors.

7. Apparatus as claimed in claim 6 wherein said means connected to said pump includes an external control arm and piston-cylinder means connected to said arm.

8. Apparatus as claimed in claim 4, wherein said pump includes selectively positionable control means for controlling the output of fluid and thereby regulating the speed of said motors, and including a piston-cylinder means connected to control means for moving said control means to selected positions.

9. Apparatus as claimed in claim 8 wherein said drive unit includes a second pump, and fluid circuit means connecting said second pump to said piston-cylinder means, said fluid circuit means including directional valve means for controlling operation of said piston-cylinder means.

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