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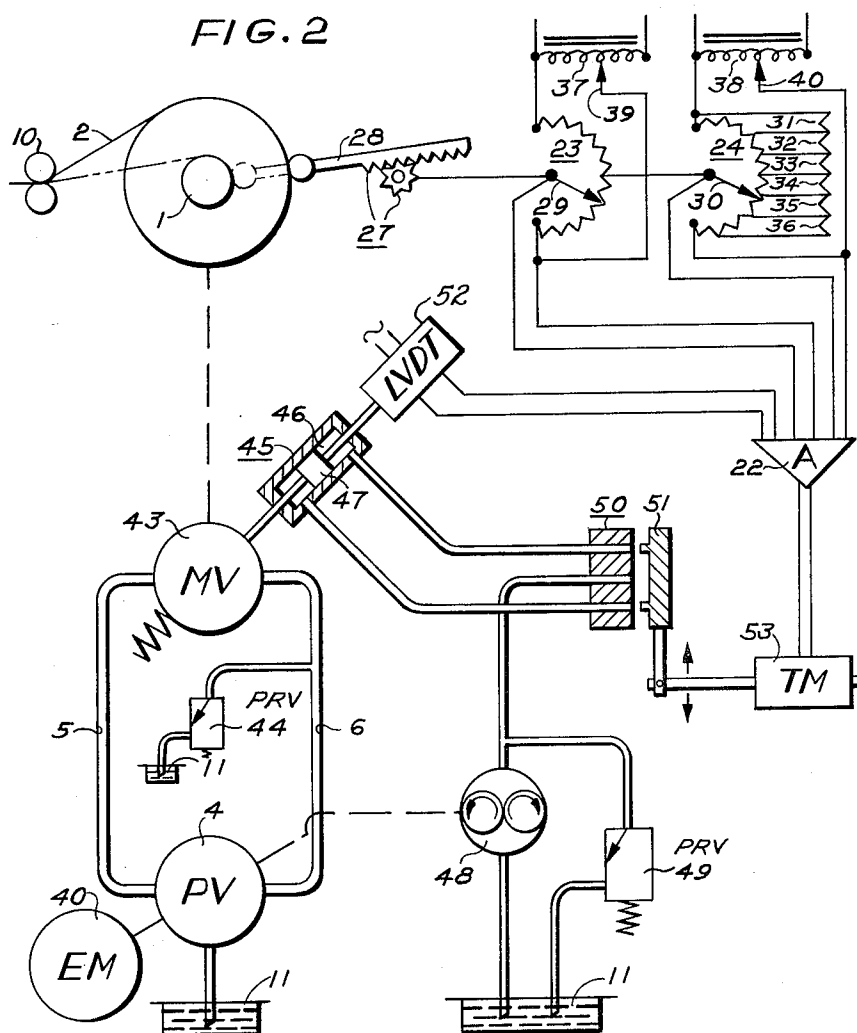
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WINDER DRIVE

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1

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WINDER DRIVE

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The invention relates to a hydraulic drive for a winder that provides for a variation in the tension of material being wound on a reel in accordance with the reel diameter.

Heretofore, the tension on paper stock being wound on a reel has been maintained substantially constant. It has been found, however, that inner layers of paper would at a constant tension tend to buckle and crimp. To avoid this the hydraulic drive, according to the present invention, includes a hydraulic motor that is controlled in accordance with reel diameter to vary the tension so that as reel diameter increases the tension the strip decreases.

It is an object of the present invention to provide a hydraulic transmission for a winder roll for winding a strip of material and controlling the transmission in accordance with the diameter of the roll so as to decrease the tension on the strip as roll diameter increases.

Another object of the invention is to provide a hydraulic drive for a winder with the drive automatically controlled so as to decrease tension on a strip being wound as a linear function of the increase in roll diameter.

Another object of the invention is to provide a hydraulic drive for a winder with control means selectively adjustable to provide a predetermined rate of change in strip tension with change in the diameter of the roll.

Another object of the invention is to provide a hydraulic drive for a winder and having electrohydraulic control means with adjustments to select the initial tension on a strip of material being wound and to select the rate of decrease in the tension with increasing roll diameter.

Other objects and advantages of the present invention will be apparent to one skilled in the art from the following descriptions and accompanying drawings, in which:

FIG. 1 is a schematic illustration of a hydraulic transmission for a winder drive embodying the present invention and shows electrohydraulic control means varying the pressure of motive fluid supplied to a load hydraulic motor having a fixed displacement.

FIG. 2 is a schematic illustration of another hydraulic transmission for a winder drive embodying the invention and shows electrohydraulic control means varying the displacement of a load hydraulic motor while the pressure of the supply motive fluid is maintained constant.

Referring to the drawings, the winder roll 1, upon which a strip of material is adapted to be wound, is driven through suitable gearing means, not shown, by a hydraulic transmission. The hydraulic transmission comprises a positive displacement hydraulic motor 3, coupled to the winder roll 1, and a positive displacement hydraulic pump 4 connected by fluid transmission lines 5 and 6 to the hydraulic motor 3. The pump 4 is driven at a constant speed by a suitable prime mover such as an electric motor, not shown. The pump 4 and motor 3 are illustrated as of variable displacement types and are manually adjustable for selecting predetermined displacements for each.

In the arrangement shown in FIG. 1, the pump and motor displacements are fixed and the torque of the motor is varied by controlling the pressure of the motive fluid supplied to the motor 3. For this purpose a pilot operated relief valve 7 is connected to transmission line 6 for limiting pump discharge pressure therein to values as controlled by the relief valve 7.

The relief valve 7 is operative to by-pass pump discharge pressure from transmission line 6 to pump return

2

or to a reservoir 11, in a known manner. The relief valve 7 has an inlet 8 connected to line 6 and an outlet 9 connected to reservoir 11. The relief valve 7 has a differential area control piston 15 which defines a control chamber 14 in an end of the valve chamber to which pressure fluid from the valve inlet is admitted through a flow restriction passage 16 arranged in a known manner. A pilot valve 13 in the relief valve 7 is operative to drain pressure fluid from control chamber 14 and discharge through part 17 in response to such pressure displacing the pilot valve 13 against the bias force of an adjustable tension spring 12, whose compression determines the pressure setting of the pilot valve.

For convenience in describing a means of controlling the transmission to effect the desired tension on a strip 2 which passes between a pair of rollers 10, it is assumed that pump 4 is discharging fluid to transmission line 6 for driving the load motor 3 and therefore the winding reel 1 in a direction to wind a strip 2 on the reel 1. If the pressure setting of the relief valve 7 were fixed then the limiting control pressure in line 6 would be maintained constant, and if such pressure were maintained constant the tension on the strip 2 being wound on reel 1 would decrease with increasing roll diameter.

Compensation for a change in diameter of the roll is provided in response to a control signal that varies in accordance with the sum of two variables; a first such variable acting alone provides a straight line compensation wherein the pressure in transmission line 6 increases directly with roll diameter for maintaining tension on the strip 2 constant; and a second such variable acting alone provides a non linear change that causes the pressure in line 6 to vary non linearly with increase in roll diameter. The resulting signal however provided by both of the variables acting together is effective to change the pressure in line 6 so that such pressure varies non linearly with increasing roll diameter so as to cause a tapering off of the tension on the strip 2. The non linear pressure change is determined by the difference of the variables which may be chosen to produce a straight line tapering off of the tension on strip 2 as it is wound on reel 1.

Tension control of the strip being wound is provided by control of the hydraulic transmission and is effected by electrohydraulic control means including the pilot operated relief valve 7 whose operating pressure is varied in accordance with the commands of the control system. The electrohydraulic control means comprises a servomotor provided by an electric torque motor 21 that rotates a screw 18 threaded through the housing of the pilot valve and changes the compression of bias spring 12. The screw 18 is coupled to the torque motor 21 by a sliding spline coupling 20.

The torque motor is energized from a voltage source, not shown, through an amplifier 22 whose output is controlled in response to input signals to the amplifier, including command and feedback voltage signals. The command voltage signals are provided by position to voltage transducers such as potentiometers 23, 24 whose adjustable tap members 29, 30 are positioned in accordance with the diameter of the winder roll 1. The feedback voltage signal is provided by a position-voltage transducer such as a linear variable displacement transformer, LVDT 26, whose movable member follows the corresponding movement of the seat or spring support 19 for the bias spring 12 of pilot valve 13. Output terminals of LVDT 26 and of the potentiometers 23, 24 are connected to the amplifier 22 in a known manner so that the voltage signal of LVDT 26 opposes the command signals of the potentiometers 23, 24.

The potentiometers 23, 24 have their rotary contacts 29, 30 connected by a shaft to rack and pinion gearing 27 whose rack 28 follows the outer diameter of the roll 1

in any known convenient manner in order to move members 29, 30 in accordance with changes in roll diameter. Actuating means for the potentiometer 23, 24 could also be provided by other devices which are operative in response to a change in roll diameter, such as actuating means that provides a displacement in accordance with the variations in the speed of the shaft of the winder roll with respect to the speed of the strip, such as is employed in U.S. Patent 2,573,938, wherein one metering pump driven at strip speed is matched with another metering pump driven at a speed corresponding to the speed of the shaft of the winder roll to establish a differential in accordance with the change in the speed of the winder roll shaft. In FIG. 1 herein the arrangement is illustrated as means directly responsive to roll diameter for positioning adjustable taps 29, 30 of the command potentiometers 23, 24.

The outer terminals of the potentiometers are connected across adjustable sources of control voltage, transformers 37, 38, having taps 39, 40 respectively, which are independently adjustable and may be ganged for adjustment together.

The command voltages of the potentiometers 23, 24 are the output voltages provided respectively by adjustable taps 29, 39 of potentiometer 23 and its supply transformer 37 and by adjustable taps 30, 40 of potentiometer 24 and its supply transformer, and these taps are connected to input terminals of the amplifier. A suitable source of alternating current voltage is provided for the energization of the amplifier and of the transformers in the control circuit.

Potentiometer 23 provides an output voltage that varies linearly with the displacement of tap member 29 and varies therefore in accordance with the diameter of the winder roll. Potentiometer 24, however, is selected to provide a voltage-resistance characteristic that varies non-linearly and preferably varies as the square of the displacement of tap member 30 and therefore as the square of the diameter of roll 1. Potentiometer 24 is a 320 degree, 7 tap, linear potentiometer with resistors 31 through 36 connected across its taps to provide step changes in the voltage-resistance characteristic that simulates the desired characteristic.

In the operation of the hydraulic drive to wind a strip of material on winder roll 1, the pump 4 and motor 3 are adjusted for selected displacements and the relief valve pressure setting initially adjusted, in a known manner, so that the drive effects a desired initial tension on the strip 2. The command and feedback signal voltages are adjusted for initial operation so as to provide zero command to the servomotor. As the strip 2 is wound on roll 1 the diameter of roll 1 increases and this increase in diameter is followed up by the actuating means provided by the rack and pinion gearing 27 and correspondingly adjusting the taps 29, 30 of the position to voltage transducers 23, 24. The resulting change in the command signal voltages causes torque motor to increase the pressure setting of the relief valve 7 until such command signal voltages are opposed by an equal feedback voltage from LVDT 26 responsive to the new limiting pressure setting of the relief valve. The system pressure P is thus controlled by control of the relief valve 7 in accordance with diameter d of the winder roll.

The pressure P of motive fluid supplied to the hydraulic motor 3 may thus be expressed as

$$p = k_a d - k_b d^2 \quad (1)$$

where d is the diameter of the winder roll and k_a and k_b are constants. Since pressure P for a drive employing a fixed displacement hydraulic motor is proportional to the product of the strip tension t and roll diameter d , the tension of the strip may be expressed as

$$t = k_1 - k_2 d \quad (2)$$

The tension according to expression 2 varies along a straight line with respect to changes in roll diameter d and the straight line may be selected providing a predetermined rate of decrease of tension with increase in roll diameter.

Adjusting the command voltages together will select an initial tension setting for the strip, and independently adjusting the command voltage to be supplied to potentiometer 24 to change its initial command voltage with respect to that of potentiometer 23 will vary the rate of decrease of strip tension with change in roll diameter while leaving the initial tension setting the same, thus providing a desired rate of tapering-off of strip tension as roll diameter increases.

Another embodiment of the invention is illustrated by the hydraulic transmission schematically shown in FIG. 2, and shows a winding roll 1 driven by a load hydraulic motor 43 as provided by a variable positive displacement hydraulic motor whose stroke is electrohydraulically controlled to also cause the strip tension to taper-off as roll diameter increases. Pump 4, FIG. 2, is adjusted to provide a fixed rate of flow to transmission line 6 for driving the load hydraulic motor 43, and the fluid pressure is limited to a selected predetermined value by means of a pressure relief valve 44 which operatively connects transmission line 6 to reservoir 11.

The electrohydraulic control means for load hydraulic motor 43 comprises a servomotor 45 operative to vary the displacement of the load hydraulic motor 43. The servomotor 45 comprises a control cylinder 46 having a double acting piston connected to the displacement member (not shown) for the hydraulic motor 43, and also connected to a follow-up voltage signal transmitting device, LVDT 52 that transmits a signal voltage in accordance with the stroke of the motor 43.

An auxiliary hydraulic pump 48, such as a gear pump, is also driven with the main pump by the prime mover electric motor 40. Auxiliary pump 48 supplies control pressure fluid to the control cylinder 46 through a servo control valve 50. Control pressure is limited to a predetermined value by a relief valve 49 operative to bypass auxiliary pump discharge to reservoir 11.

The servo control valve 50 has a flat plate valve member 51 that normally blocks communication between ports to opposite ends of the control cylinder and to the auxiliary pump in a known manner. The flat plate valve member 51 is subject to rectilinear displacement in accordance with the energization of an electric torque motor 53 that is energized by the output of amplifier 22. The amplifier 22 receives a feedback signal voltage from LVDT 52 in accordance with the stroke of the motor 43 and receives command voltages to vary the stroke of the motor 43 from the potentiometers 23, 24 in accordance with roll diameter.

The hydraulic drive of FIG. 2 provides that the torque T of the load hydraulic motor shall vary with the product of the displacement dm of the load hydraulic motor and the pressure P of the motive fluid supplied to it. The fluid pressure is a constant, k , and the displacement dm is varied in accordance with the sum of $k_a d - k_b d^2$ whose values vary, respectively, with roll diameter and with the square of the roll diameter and are provided by the command signals transmitted by potentiometers 23, 24, respectively. The value of torque T for a given pressure P may be expressed as

$$T = kdm = k_a d - k_b d^2 \quad (3)$$

and since tension t varies with torque T and inversely with roll diameter d so that the value of the tension t is thus also given by an equation in similar form to Equation 2 above

$$t = 2k_a - 2k_b d \quad (4)$$

Thus the hydraulic drive of FIG. 2, like that of FIG. 1, provides a straight line characteristic of strip tension versus roll diameter to provide a straight line change in

5

tension with roll diameter, and any desired rate of tapering-off of strip tension with increasing roll diameter can be obtained.

While but two embodiments of the invention have been shown and described wherein line pressure is controlled utilizing a relief valve while motor displacement is held constant, and wherein line pressure is held constant while motor displacement is controlled, it will be apparent that application of a dual command signal, one varying linearly with roll diameter and the other as the square of the roll diameter, may be variously employed to control pump or motor displacement so as to control the torque of the load motor as a function of roll diameter, in accordance with the spirit of the invention described and claimed herein.

I claim:

1. In a hydraulic transmission for a winder roll operative to control the tension on a strip of material being wound, a winder roll, an electrohydraulic control means including a first command signal transmitting means providing a voltage signal that varies linearly with changes in the diameter of the roll, and including in combination therewith a second command signal transmitting means providing a voltage signal that varies non linearly with changes in the diameter of the roll and operatively connected with the first command signal transmitting means to cause the electrohydraulic control means to decrease the tension of the strip as a function of roll diameter.

2. In a hydraulic transmission for a winder roll as defined in claim 1 in which the electrohydraulic control means comprises a servomotor whose displacement controls the torque of a hydraulic motor driving the winder roll, said first and second command signal transmitting means being positioned to voltage transducers operable in accordance with roll diameter and having outputs connected to an amplifier controlling the servomotor, a feedback signal transmitter providing a voltage signal that varies linearly with the displacement of the servomotor and having an output connected to the amplifier to oppose the command signals, said first signal transmitting means providing a voltage that varies linearly with roll diameter and said second signal transmitting means providing a voltage that varies as the square of the roll diameter, thereby controlling motor torque so as to decrease strip tension linearly with increase in roll diameter.

3. In a hydraulic transmission for a winder roll as defined in claim 1 in which the first and second command signal transmitting means are independently adjustable to vary the magnitude of their signals and have displacement members adjustable to vary the rate of decrease of strip tension with increase in roll diameter.

4. In a hydraulic drive for rotating a roll for winding a strip of material in which the rotary speed of the roll decreases relative to the linear speed of the material so that the tension on the strip of material decreases gradually as the diameter of the roll increases, a winder roll, electrohydraulic control means responsive to the diameter of the roll for varying the pressure of motive fluid supplied to the load hydraulic motor, said electrohydraulic control means comprising a servomotor for controlling the pressure of said motive fluid and first and second position signal transducers that are positioned in accordance with roll diameter, said first position signal transducer providing a command signal to said servomotor that varies linearly with said roll diameter, said second position signal transducer providing a command signal to said servo motor that varies as the square of the roll diameter and a third position signal transducer providing an opposing signal to said servomotor that varies linearly with the displacement of the servomotor; whereby the pressure of motive fluid applied to the load

6

hydraulic motor varies with roll diameter so as to gradually decrease tension of the strip with increase in roll diameter.

5. A control system for a hydraulic drive for a winder roll driven by a hydraulic motor, a winder roll, a pump connected by transmission lines to said hydraulic motor, a relief valve operatively connected to one of the transmission lines for limiting the line pressure of motive fluid supplied to the hydraulic motor, a pilot valve for the relief valve adjustable to determine the operating pressure of the relief valve, servomotor means for adjusting the pressure setting of the pilot valve comprising an electric torque motor coupled thereto, an amplifier controlling the energization of the torque motor in accordance with first and second command signals transmitted to the amplifier and a feedback signal opposing said command signals, said first and second command signals varying, respectively, with the diameter of the winder roll and with the square of the diameter of the winder roll, and the feedback signal varying with the pressure setting of the pilot valve, whereby the tension on the strip decreases gradually as roll diameter increases.

6. A control system for a hydraulic drive for a winder roll driven by a load hydraulic motor, said winder roll varying in diameter as it rotates, a pump supplying motive fluid to said load hydraulic motor, a pressure relief valve operatively connected to by-pass discharge fluid from said pump to limit pump discharge pressure in accordance with the diameter of the winder roll, a pilot valve controlling the operating pressure of the relief valve and including an adjustable spring tension bias means, and a servo control means including an electric torque motor operable to vary the tension of the spring and an amplifier controlling the energization of the torque motor, signal means connected to the amplifier comprising a first signal means providing a voltage in accordance with the diameter of the winder roll, a second signal means providing a voltage in accordance with the square of the diameter of the winder roll, and a third signal means providing a voltage in accordance with the pressure setting of the relief valve, whereby the tension of a strip of material being wound is gradually decreased as roll diameter increases.

7. A control system for a hydraulic drive for a winder roll driven by a variable displacement hydraulic motor, said winder roll varying in diameter as it rotates, a supply of motive fluid at constant pressure for said hydraulic motor, electrohydraulic control means for varying the displacement of the hydraulic motor comprising a hydraulic servomotor, a source of control pressure fluid, a servo valve connected to the servomotor and operable to control the admission of control pressure fluid to the servo motor, an electric torque motor coupled to the servo valve, an amplifier controlling the energization of the torque motor, and signal means connected to the amplifier for controlling its output, said signal means comprising first and second voltage transmitting means that provide voltages, respectively, in accordance with the diameter of the winder roll and the square of said diameter, and third voltage transmitting means that provides a voltage in accordance with the displacement of the hydraulic motor, whereby the tension of a strip of material being wound varies linearly with roll diameter.

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MERVIN STEIN, *Primary Examiner.*