

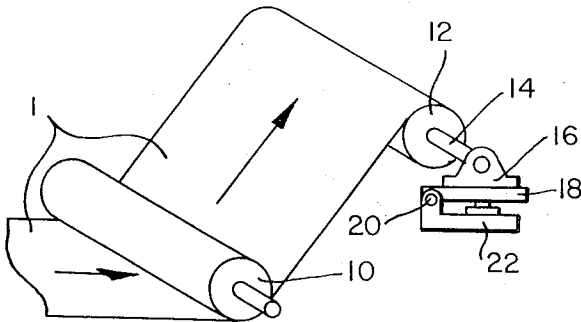


FIG. 1

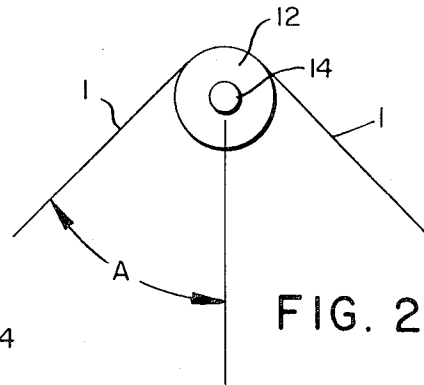


FIG. 2

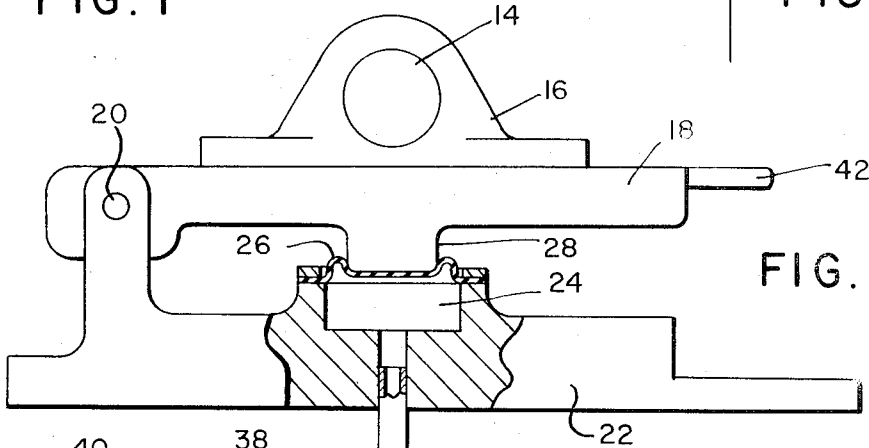


FIG. 3

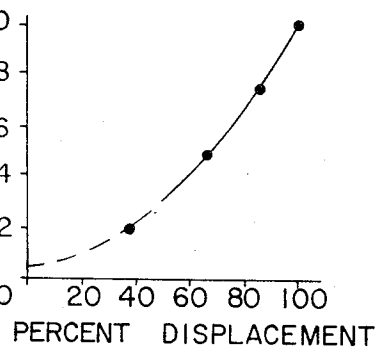
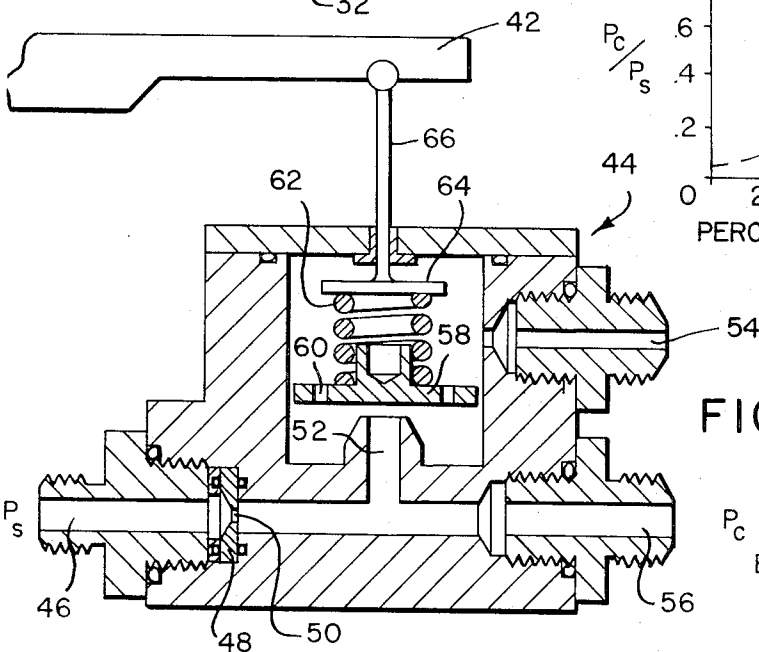
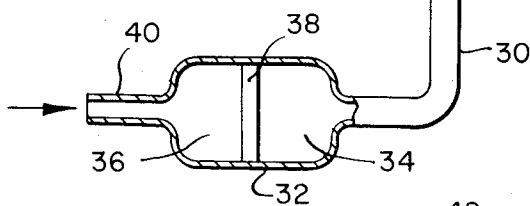
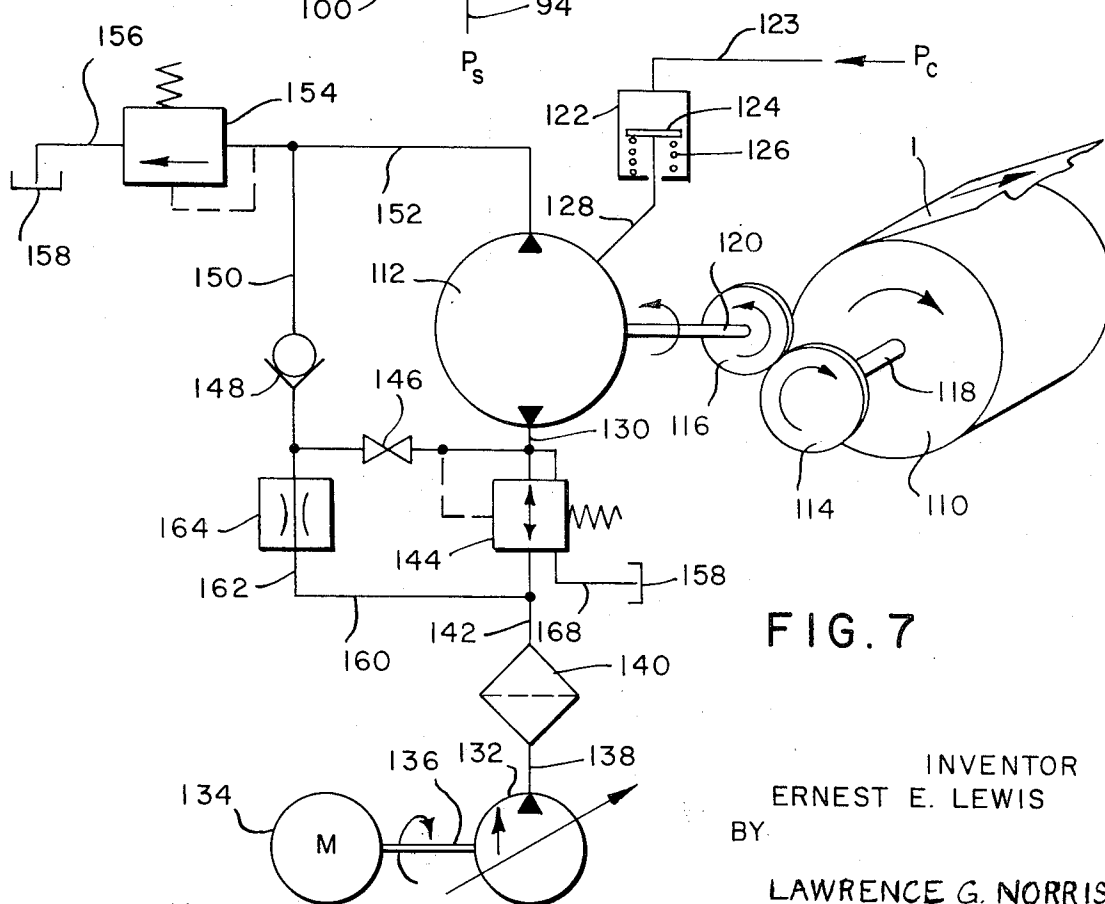
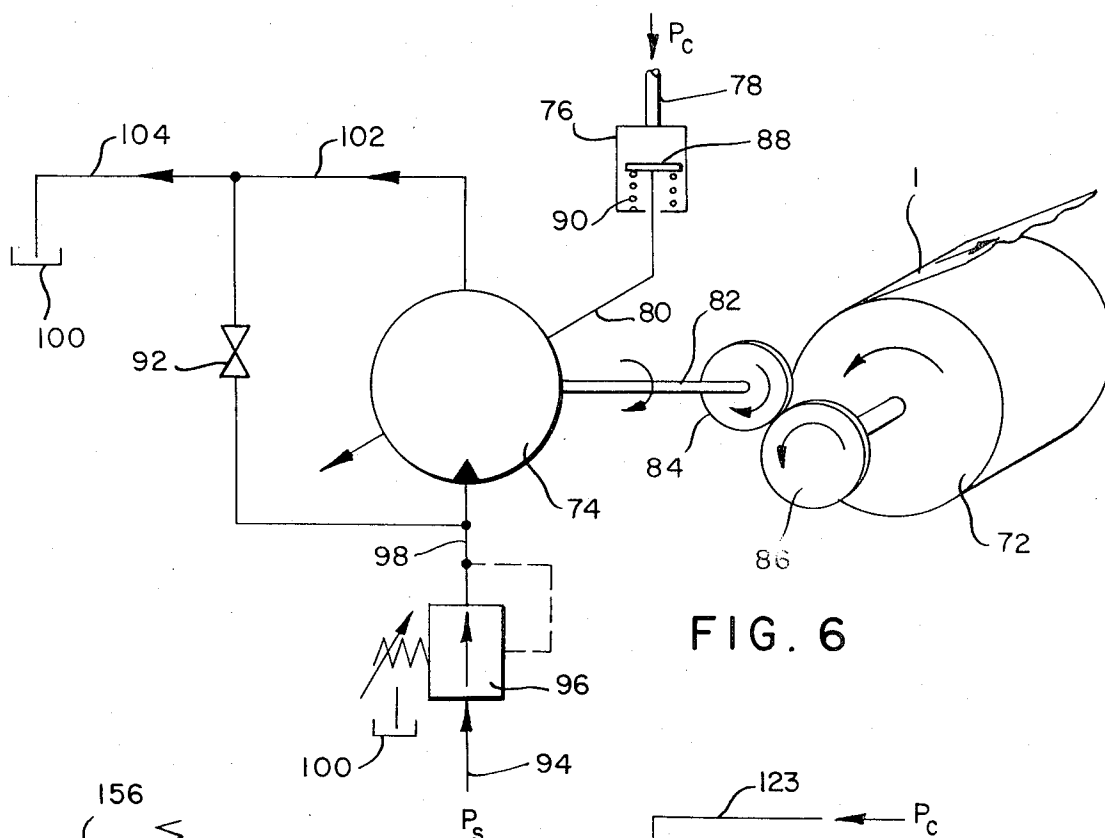


FIG. 5

FIG. 4

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TENSION CONTROL SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

In the paper, metal, film processing and similar industries there occurs, in the execution of various processes involving the movement and control of the stock material in web form, the need for unwinding the web material from a roll, operating on the web, and then rewinding it again onto another roll. In some cases, the operation may involve the unwind step only, such as where the web is consumed in the manufacture of another product. In other cases, only a rewind operation may be involved.

The field of the invention relates to the control of web tension in systems of the aforementioned type, both in response to set point adjustment and in response to error signals resulting from deviations about the set point.

2. Description of the Prior Art

In the typical application of tension control systems of the aforementioned type, it is often required that the system handle webs of widely differing characteristics, thereby necessitating a relatively large tension operating range for both the unwind and rewind equipment. Metals, for example, often require high values of tension while plastic films need very little.

In addition, the actual level at which the tension is set must be maintained quite accurately even under rapidly varying types of disturbances, such as can occur while splicing, pasting, starting, stopping and performing various other steps typical of web processing applications. This requires a system capable of very rapid response and having a high degree of sensitivity with respect to small but often rapid changes in web tension about the set point level.

In the past, many types of mechanical, hydraulic and electrical devices have been utilized to provide tension control for winder and unwinder operations. To give some examples, friction brakes, electric motors and generators, eddy current devices and hydraulic pumps and motors have all been utilized in such applications. All of these have suffered from one or more deficiencies, such as a limited tension control range, sluggish response to system disturbances, high internal friction contributing to losses and limiting the minimum tension control set point in a manner to be explained, high cost, low sensitivity to tension changes, low reliability, poor static control and adjustment to the tension level, high interaction with the controlled process, and extreme complexity.

For example, in the application of hydraulic units to such systems, it has been a common practice to employ, in the winding type operation, a fixed displacement hydraulic motor to drive the winding coil against the force on the web exerted by the process with speed and tension being regulated by controlling the pressure or flow rate of hydraulic fluid supplied to the motor. This control has typically been accomplished by means of a variable displacement pump whose adjustment is controlled by the position of a so-called "dancer" roll riding on the moving web. As the tension decreases below the set point, the web sags to cause a downward deflection of the dancer roll, thereby yielding a tension error signal. Conversely, as the tension increases above the set point, the web is drawn more taut, thereby ele-

vating the dancer roll and yielding an error signal of reverse polarity. This error signal is then utilized to adjust the stroke of the variable displacement pump to control flow to the fixed displacement motor.

In a hydraulic system of the type just described, the parameter which directly controls web tension is the flow rate of hydraulic fluid to the motor. In order to accommodate a range of tension set points, all of the hydraulic elements in the system must therefore be sized to accept the maximum flow rate required. The result is that the hydraulic elements, the pump, line sizes and so on, are oversized for the normal operating ranges. In addition, since the dancer roll rests directly on the moving web, there is a direct interaction with the process which can interfere with or cause disturbances to the process itself.

Similar deficiencies exist in the case of the application of hydraulic units to unwinder operations. In addition, various difficulties of the nature previously described above are encountered in application of other kinds of devices, such as motors, generators, and eddy current devices.

It is a primary object of this invention to provide an improved hydraulically powered tension control system which offers substantial advantages over hydraulic systems previously employed and over other types of systems as well.

SUMMARY OF THE INVENTION

Briefly described, the invention proposes, in one form thereof, the combination of a unique tension set point and error detection system with variable displacement hydraulic pumps and motors and related control devices arranged to permit direct control of the parameter which produces web tension, namely torque. In the winder application, where the winder roll is driven to pull the web against the retarding force of the process, the controlled parameter is the output torque of a variable displacement motor driving the winder roll. In the unwind application, where the process pulls the web from the roll and tension is provided by a retarding torque on the unwind roll, a variable displacement pump is connected as a load on the unwind roll so as to permit control of the retarding torque through adjustment of pump displacement. The variable displacement units are preferably operated at substantially constant, regulated hydraulic pressure, the steady state level of which may be adjustable, to provide unique control advantages hereinafter explained in detail.

The system offers substantial advantages over systems available in the prior art. These advantages together with other unique features of the invention will be described in detail in the specification which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of a portion of a web handling system employing a guide roll embodying tension sensing means in accordance with the present invention;

FIG. 2 is an end view of the guide roll of FIG. 1 illustrating the nature of the web force exerted on the roll;

FIG. 3 is an enlarged schematic view of a portion of the tension sensing apparatus of FIG. 1;

FIG. 4 is an enlarged cross-sectional illustration of another portion of the tension sensing apparatus of FIG. 1;

FIG. 5 is a graphical representation of the pressure relationships developed by the apparatus of FIG. 1 in response to input displacement;

FIG. 6 is a schematic presentation of a winder system embodying the present invention; and

FIG. 7 is a schematic presentation of an unwinder system embodying the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, there is illustrated in FIG. 1 a schematic diagram of a portion of a web tension control system embodying the invention. In this application, there is illustrated a web 1 passing through a process and running between guide rolls 10 and 12. The guide rolls 10 and 12 are supported in suitable bearing means, not shown.

An end view of the guide roll 12 is shown schematically in FIG. 2. It will be observed that as the web 1 passes in tension over the guide roll 12, a downward force will be exerted on the roll 12, which force will be a function of the tensile force in the web and the angle A between the plane of the web and the vertical, which angle is usually referred to as the "wrap angle." For any given wrap angle, an increase in web tension will result in a proportional increase in the downward force exerted on the roll 12, and vice versa.

Referring again to FIG. 1, one end shaft 14 of roll 12 is supported in a bearing 16 which in turn is supported on a base plate 18. The base plate 18 is pivotally mounted at 20 on a frame member 22 which is a part of the fixed structure of the machinery.

The particulars of the bearing mounting arrangement just described are shown in FIG. 3. Formed in the frame member 22 is a cylinder 24 arranged to interact through a flexible diaphragm 26 with a piston 28 on the lower side of the base plate 18. The cylinder 28 is connected through hydraulic line 30 to an air-oil interfacing device 32.

The separator 32 is formed of two chambers 34 and 36 which are separated and sealed from each other by a movable piston 38. The volume formed by the cylinder 24, line 30 and chamber 34 is filled with hydraulic fluid while air under pressure is supplied to chamber 36 through a line 40.

In the arrangement just described, it will be observed that the downward force on the guide roll 12 is transmitted through its bearing 16 and the hinged base plate 18 to the hydraulic fluid in the cylinder 24 from the piston 28 and through the diaphragm interface 26. This force is in turn ultimately opposed by the air pressure supplied to the chamber 36, which pressurizes the hydraulic fluid through the piston interface 38.

Assuming an equilibrium condition where the forces just described are in opposing balance, an increase in web tension will cause a downward deflection of the base plate 18 while a decrease in web tension will produce an upward deflection.

Referring again to FIG. 3, there is attached to the base plate 18 a control arm 12 which moves up and down with the base plate 18 in response to variations in web tension. The control arm 42 is in turn connected to a tension error sensing device 44 which is shown in cross-section in FIG. 4.

The tension error sensing device 44 is a device to which a fluid, preferably hydraulic fluid, under pressure is supplied through an inlet port 46. Downstream

of the inlet port 46, there is positioned a plate 48 having therein a fixed diameter orifice 50.

Downstream of the orifice 50, fluid flow is divided into two paths, one being through a so-called "flapper" discharge port 52 and thence to the system reservoir or drain through port 54, and the other being through a control pressure discharge port 56. Since the port 56 is of fixed dimensions, the total flow through orifice 50, and hence the pressure drop across it, is determined by the effective area at the discharge of flapper port 52.

The effective area of the flapper port is controlled by means of a flapper element 58 which has therein a series of venting orifices 60 and which is movable within a cylindrical chamber 62 toward and away from the flapper discharge port 52. When the flapper element 58 is moved closer to the discharge port 52, the restriction on gas flow out of the port 52 is increased, or, in other words, the effective area of the discharge port 52 is decreased. Conversely, when the flapper element 58 is moved away from the port 52, the effective area of the discharge port is increased.

To translate the foregoing into its effect on the control pressure at the port 56, when the flapper element 58 is moved away from the port 52, gas flow through the orifice 50 is increased, thereby increasing the pressure drop across the orifice 50 and decreasing the control pressure at port 56. The analysis herein presented assumes that the steady state flow through the port 56 is negligible, this being essentially the leakage flow into the control actuation system, and that accordingly changes in control pressure at the port 56 are produced predominantly by variations in flow through port 52 affecting the pressure drop across the orifice 50. Following this analysis, as indicated above, movement of the flapper element 58 away from the port 52 increases the flow therethrough, increasing the pressure drop across orifice 50, and decreasing the control pressure at port 56. Conversely, movement of the flapper element toward the port 52 decreases the flow therethrough, decreasing the pressure drop across orifice 50 and increasing the control pressure at port 56. The foregoing assumes, of course, that the supply pressure at inlet port 46 is held at a substantially constant value. The flapper element 58 is connected to the control arm 42 through a spring 62, which engages a washer element 64, which is in turn attached to a stem 66 secured to and extending from the control arm 42. The purpose of the spring 62 is to act as a transducer for converting displacement to force by developing a force against the flapper element 58 responsive to displacement of control arm 42.

The approximate nature of the relationship between the ratio of control pressure at port 56 (designated P_c) over the supply pressure at inlet port 46 (designated P_s) as a function of percent deflection of the control arm 42 in the downward direction (as depicted in FIG. 4) is set forth in FIG. 5. At the 100 percent deflection point, the port 52 is completely closed and the ratio of P_c over P_s is unity. Over the range of normal operation, the control pressure P_c increases in a generally proportional relationship (for constant P_s) as a function of the downward deflection of control arm 42.

Thus far, there has been described a means for adjusting the tension set point, that is by adjusting the value of the air pressure at line 40 (FIG. 3) to effect a change in the force balance previously explained, as well as a means for sensing variations in web tension

about the set point, this latter function being achieved through response to the error sensing device 44 to movements of the control arm 42, which produces corresponding variations in the control pressure P_c at port 56 (FIG. 4).

Turning now to FIG. 6, there is shown a drive system for a winder tension control embodying the present invention and operable in response to the tension set point and error signals produced by the portion of the system just described. The system of FIG. 6 is represented in schematic form since the individual elements which make up the system, such as the hydraulic drive unit, actuator, bypass valve and the like are in themselves well known components in the art. Detailed description of these individual elements is therefore not presented.

In the winder system of FIG. 6, a web 1 is being wound onto a winder roll 72 with the tension in the web 1 being determined by the driving torque on the roll 72 pulling the web against the resisting force being exerted by the process. In accordance with the invention, the roll 72 is driven by a variable displacement hydraulic motor 74, which may in itself be a conventional type of device such as a radial ball piston motor having an annular race whose concentricity may be adjusted relative to the center of rotation of the cylinder block to control motor displacement.

The adjustment of motor displacement, or stroke as it is sometimes called, is controlled by an actuator 76 which is in turn connected through line 78 to respond to control pressure P_c produced at port 56 by the error detecting device shown in FIG. 4. The connection of the actuator 76 to the stroke control of motor 74 is shown schematically by arrow 80 for reasons of simplicity and convenience of illustration, it being understood that the mechanization of such a connection can be accomplished in a number of well known ways. The motor 74 is connected in driving relationship to the winder roll 72 through a motor output shaft 82, and gears 84 and 86, the latter three elements all being represented in schematic form.

The piston 88 of actuator 76 is spring loaded by means of a spring 90 in a direction to adjust the hydraulic motor 74 to its maximum displacement setting. In other words, with the control pressure P_c at a zero gauge level, the motor 74 is set at the maximum stroke condition by the action of spring 90. The significance of this feature will be explained later.

The motor 74 is provided with a bypass valve 92 which may be activated to bypass hydraulic fluid around the motor to allow the roll 72 to be rotated with the system deenergized. Hydraulic fluid is supplied to the motor from a pressurized source through an input line 94, and thence through a pressure regulating valve 96 which operates in a conventional manner to provide a regulated and substantially constant pressure at its output 98, which is also the input to the motor 74. The steady state level of the hydraulic pressure may be, and preferably is, adjustable in order to permit adjustment of the range of the system. Hydraulic fluid discharged from the motor 74 is returned to the system reservoir, represented schematically at 100, through discharge lines 102 and 104. It will be observed that the bypass valve 92 is also connected to discharge into the system reservoir through line 104.

Thus, in the system shown in FIG. 6, the driving torque on winder roll 72 is supplied by the variable displacement

motor 74, whose stroke or displacement is controlled by the actuator 76 in response to control pressure P_c and whose input hydraulic pressure at line 98 is regulated to a substantially constant magnitude.

As indicated earlier, the level of control pressure P_c is determined by (1) the steady state setting of the pressure at line 40, which establishes the equilibrium or force balance position of base plate 18 acting through control arm 42 to adjust web tension and (2) any deviations in the web tension from the set point level which cause movement of control arm 42 to yield changes in control pressure P_c proportional to web tension error.

The details of operation of the system just described will now be set forth.

Assume that a set point pressure has been applied through line 40 to chamber 36, thereby providing a corresponding hydraulic pressure equilibrium level in cylinder 24 through the interface of piston 38. Under these conditions, the system will arrive at the corresponding web tension level which represents a force balance between the downward force on bearing 16 and the resisting upward force against piston 28. This is being accomplished in the manner described above with the control arm 42 operating through the flapper device 44 to yield a resulting control pressure P_c , which in turn adjusts the stroke of hydraulic motor 74 through actuator 76 to apply the required driving torque to winder roll 72.

Now assume that by reason of a disturbance in the system, the tension in the web 1 increases above the set point level. This causes a downward deflection of control arm 42, thereby increasing the restriction on flow through the flapper port 52. This in turn reduces the pressure drop across the orifice 50 and causes an increase in control pressure P_c at discharge port 56. The increase in control pressure P_c causes movement of piston 88 of actuator 76 (FIG. 6) against spring 90 to decrease the displacement of the hydraulic motor 74.

The decrease in displacement in motor 74, which is operating at substantially constant inlet pressure, produces a decrease in the output torque of the motor, thereby decreasing the tension in the web 1 until a force balance is again restored with the tension returned to the set point level.

Conversely, a decrease in tension in the web below the set point level causes an upward movement of the guide roll 12 by reason of the excess force exerted in the upward direction on piston 28 by the hydraulic fluid under pressure in cylinder 24. This in turn moves the control arm 42 in the upward direction, decreasing control pressure P_c , and thereby permitting spring 90 of actuator 76 to move the piston 88 in a direction to increase the displacement of motor 74. The increase in displacement of motor 74 increases its driving torque on roll 72 until the tension is again increased to the set point level.

Before setting forth further features of the invention, the operation of the invention in an unwind system embodiment will now be described. This is illustrated in FIG. 7, again with the elements being depicted in schematic form.

In this embodiment, the web 1 is being pulled by a force exerted by the process from an unwind roll 110 against a resisting torque imposed on the roll 110 by a hydraulic pump 112 connected in driven relationship through gears 114 and 116 from roll shaft 118 and pump shaft 120.

The pump 112 is of the variable displacement type and, as illustrated schematically, is controlled by an actuator 122 comprising a piston 124 and spring 126. The connection from the actuator 122 to the displacement control of the pump 112 is illustrated schematically by line 128 and may be of any convenient and well known form. The actuator 122 is controlled in response to control pressure P_c connected through line 123 from port 56 (FIG. 4).

The pump 112 is supplied with hydraulic fluid at its inlet 130 by a positive variable displacement, pressure compensated boost pump 132 which is in turn driven by an electric motor 134 connected through suitable shafting 136. Hydraulic fluid is discharged at line 138 from the boost pump 132, thence through a filter 140, line 142 and pressure regulator 144 to the main pump inlet 130. The pressure regulator 144 may be of any well known type and is set to maintain the hydraulic pressure at pump inlet 130 at a substantially constant, preferably adjustable, preselected value.

The pump 112 may be bypassed by a manually operable bypass valve 146 connected through a check valve 148 in line 150 to discharge line 152 of the pump 112. The discharge pressure of pump 112 at line 150 is regulated to a substantially constant value by a pressure regulator 154 which is connected in line 156 to system reservoir 158.

Line 142 is connected, for reasons later to be described, through an alternate flow path comprising line 160, line 162, and flow limiting valve 164 to line 150 containing the check valve 148. Flow limiting valve 164 may be of any well known type and is set to limit the hydraulic fluid flow rate therethrough at a preselected maximum rate.

The pressure regulating and flow limiting valves described above may be of any type well known in the prior art. These valves may be of the bypass or dumping type, except that it should be noted here, again for reasons to be explained later, that pressure regulator 144 is capable of regulating the pressure at its discharge to a substantially constant value for hydraulic fluid flow therethrough in either direction. The pressure regulator 144 is shown connected through a dump line 168 to the system reservoir 158.

The operation of the unwinder tension control system of FIG. 7 will now be described.

Referring back to FIGS. 1 and 3, assume that the set point pressure in line 40 is adjusted to a preselected level representing a desired tension level in the web. This is in turn transmitted in a manner previously described to the hydraulic fluid in cylinder 24 which exerts an upward force on cylinder 28 and hence the guide roll 12. In deviations from the set point pressure in the downward pressure exerted by the guide roll 12 are sensed in the form of upward or downward movements of control arm 42 which are in turn reflected as variations in the control pressure P_c at port 56 of device 44 (FIG. 4). This control pressure P_c is connected to operate actuator 122 through line 123 as shown in FIG. 7.

Piston 124 adjusts the displacement of pump 112 in a manner previously described to adjust the loading torque imposed by the pump on unwind roller 110, which unloading torque in resisting the pulling force exerted by the process on web 1 in turn determines the level of tension in web 1. As in the case of the winder system illustrated in FIG. 6, the piston 124 of actuator

122 is loaded by the spring 126 in the direction of maximum displacement of the loading pump 112.

Thus, for a particular tension set point as represented by a preselected pressure level applied at line 40 (FIG. 3), the resulting control pressure P_c applied to actuator 122 at line 123 adjusts the displacement of the pump 112 to a level which regulates the tension in web 1 to the set point level. Since the pump inlet and discharge pressures are regulated at substantially constant levels, the retarding torque is approximately a direct function of pump displacement. Flow through the pump is a function of pump speed and displacement.

Now assume a momentary increase in web tension above the set point level.

As explained above, an increase in web tension will cause a downward deflection of guide roll 12 against the pressure in cylinder 24 and produce a corresponding downward deflection of control arm 42. This, in turn, causes a reduction in flow through the flapper orifice 52 and an increase in control pressure P_c at port 56 of the flapper device. The increase in control pressure P_c , which is applied to actuator 122 through line 123, causes a deflection of actuator piston 124 against spring 126 in a direction to decrease the displacement of pump 112.

The decrease in displacement of pump 112 reduces the retarding torque exerted by the pump on unwind roll 110 to reduce the tension on the web 1. This process of correction continues until the web tension is restored to the set point level and the aforementioned force balance between the downward force on the guide roll 12 exerted by web 1 and the upward force exerted by the pressure in cylinder is again achieved.

Similarly, system disturbances which cause a reduction in web tension below the set point level cause an increase in pump displacement to raise the tension level back to the set point or reference magnitude.

It is to be noted that the mounting of guide roll 12 is not limited to a vertical deflection mode as depicted in FIGS. 1 through 3. The same technique of sensing tension level could be used, for example, with the web running in a generally vertical direction and exerting a horizontal force against the guide roll, with this force in turn being balanced by an opposing horizontal force generated by the set point pressure level. In such a case, the arrangement of elements shown in FIGS. 1 through 3 would be rotated 90°.

Returning again to the operation of the system shown in FIG. 7, an important advantage achieved in this embodiment of the invention is its ability to operate at very low tension levels. It will be apparent from the foregoing description that, with the variable displacement pump 112 operating in its pumping mode, the point of minimum controllable tension is approached as the pump displacement is adjusted to zero. The web tension at this point will not, however, be reduced to zero because of the remaining retarding force exerted on the unwind roll 110 by the internal friction torque of the pump, gearing, bearings and the various other elements of the system.

The system shown in FIG. 7 is capable of reducing the controlled web tension below the aforementioned seemingly inescapable limit by reason of its ability to adjust the pump 112 into a motoring mode. For this application, the pump 112 is provided with a displacement range permitting adjustment beyond the zero

point. This type of variable displacement pump is well known in the art.

As the displacement of pump 112 is stroked through the zero level and into the motoring mode, the direction of hydraulic fluid flow through the pump 112 is reversed. In this mode, fluid from the boost pump 132 flows through line 138, filter 140 and line 142 whence it then flows through lines 160 and 162, flow limiting valve 164, check valve 148 and lines 150 and 152 into what is normally the discharge of pump 112, but is now the inlet in the motoring mode. The fluid is then discharged through line 130, pressure regulating valve 144 and line 168 into the system reservoir 158. The flow limiting valve 164 prevents an excessive flow from being drawn from the boost pump 132 through the regulator 154 to the reservoir 158 and also limits the maximum flow rate through the pump 112 in its motoring mode.

With pump 112 operating in the motoring mode as just described, very low values of controllable web tension, approaching zero, can be achieved by reason of the driving action of the pump overcoming the retarding action of the frictional forces described above. In this mode, the pump 112 actually assists the unwind action by driving the roll 110 in the unwind direction.

It is to be noted that in both wind and unwind embodiments of the invention the variable displacement hydraulic units which apply the driving or retarding torques to the system are operated at a substantially constant hydraulic pressure. This allows for direct control of that parameter which produces web tension, namely, torque. In addition, the tension sensing means of FIGS. 1 through 4 provides a large and powerful signal proportional to web tension variations about the set tension level, with which to control the variable displacement hydraulic units. The small excursions required of the control arm 42, which in a typical application may be in the order of twenty thousandths of an inch and almost always less than one tenth of an inch full range, cause little disturbance to or interaction with the process as compared to those disturbances introduced by some systems employing "dancer" rolls weighing many pounds and traveling in some cases several feet. The tension control system of the present invention is therefore highly responsive to small tension variations, produces a highly amplified signal and has negligible interaction with the process being controlled.

The system also provides for ready and direct adjustment of the set point tension and thus allows for greater ease of control in such systems as those requiring "taper tension" control. Consider, for example, a winder system in which a constant web tension is desired to be maintained as the web material is wound onto the roll. As the material is wound onto the roll, the diameter of the wound web increases and, if constant tension is to be maintained, the driving torque required at the roll shaft must increase as the roll diameter increases. And, if an essentially constant web surface lineal speed is to be maintained, then the roll shaft speed must decrease as the roll diameter increases. The motor stroke or displacement must therefore be increased with increasing roll diameter to produce the combination of increasing torque and decreasing speed with increasing roll diameter. The system of the present invention accomplishes the foregoing smoothly and automatically. The same will be apparent in the case of

the unwinder embodiment. The system is also capable of maintaining full tension under stall conditions indefinitely. The tension range over which the system can operate is also adjustable through adjustment of the steady state regulated pressure level at which the hydraulic units are operated. In addition, operation of the variable displacement hydraulic units at substantially constant steady state pressure allows the system to operate, in a typical winder or unwinder application, at a substantially constant hydraulic fluid flow rate, thereby permitting the realization of substantial economies in the sizing of hydraulic flow lines and other elements of the system as contrasted to prior art systems in which widely varying flow rates are required to be accommodated.

Several other features of the invention should also be noted. As shown in FIGS. 6 and 7, the actuators which control the adjustment of hydraulic unit displacement are spring loaded in the direction of maximum unit displacement, corresponding to minimum unit speed for a given flow rate. This means that in the event of control signal loss, the hydraulic units are automatically set to their minimum speed setting. In addition, in the case of the unwinder system of FIG. 7, the motoring mode of the pump 112 not only provides for very low values of controllable web tension, but also allows use of the motoring mode to assist in start-up and threading operations.

It will be apparent from the foregoing that the tension control system of the present invention provides a number of advantages over prior art systems. It should be realized, of course, that the embodiments herein presented are for purposes of description and are not intended to be limiting. Accordingly, it will be obvious that various changes, modifications and substitutions may be made in the embodiments herein presented without departing from the true scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a web handling system of the type in which a moving web is wound onto or unwound from a roll with the tension in the web being determined, in the case of winding the web onto the roll, by a driving torque exerted by drive means on the roll against a retarding force on the web, and, in the case of unwinding the web from the roll, by a retarding torque exerted on the roll by retarding means against a pull unwinding the web from the roll, an improved tension control system comprising:

a variable displacement hydraulic unit connected to the roll to exert a driving or retarding torque thereon;

means for supplying hydraulic fluid under pressure to said unit and for regulating the magnitude of the pressure of said hydraulic fluid as supplied to said unit to provide a preselected relationship between the displacement and the output torque of said unit;

means for generating a web tension reference signal representing the set point level of tension desired in said web;

means for sensing the magnitude of the tension in said web and generating a signal in proportion thereto;

means for sensing the difference between said reference signal and said tension proportional signal and

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for generating a web tension error signal as a function of said difference; and

means for adjusting the displacement of said hydraulic unit responsive to both the magnitude and direction of said tension error signal to vary directly the driving or retarding torque exerted by said hydraulic unit in a direction to decrease the magnitude of said tension error signal.

2. A web tension control system as set forth in claim 1 in which said means for regulating the pressure of the hydraulic fluid supplied to said hydraulic unit is set to maintain said pressure at a substantially constant preselected level.

3. A web tension control system as set forth in claim 2 including manually operable valve means connected to permit bypassing of hydraulic fluid from the supply around said hydraulic unit to relieve the hydraulic pressure on said unit and permit free wheeling of said unit and the roll to which it is connected.

4. In a web handling system of the type in which a moving web is wound onto or unwound from a roll with the tension in the web being determined, in the case of winding the web onto the roll, by a driving torque exerted by drive means on the roll against a retarding force on the web, and, in the case of unwinding the web from the roll, by a retarding torque exerted on the roll by retarding means against a pull unwinding the web from the roll, an improved tension control system comprising:

a variable displacement hydraulic unit connected to the roll to exert a driving or retarding torque thereon;

means for supplying hydraulic fluid under pressure to said hydraulic unit;

means for regulating the pressure of the hydraulic fluid supplied to said hydraulic unit to provide a preselected relationship between the displacement and the output torque of said unit;

guide roll means engaging said moving web in such a manner that the force exerted on said guide roll means by said web is a function of the tension in said web;

movable support means engaging said guide roll means to permit movement of at least one end of said guide roll means;

force generating means for applying a reference force to said movable support means in opposition to the force exerted on said guide roll means by said web, said reference force representing the set point level of tension desired in said web;

means for sensing movement of said movable support means in response to a force unbalance between the tension proportional force exerted on said guide roll means by said web and the opposing reference force exerted by said force generating means; and

means for adjusting the displacement of said variable displacement hydraulic unit responsive to said movement sensing means to vary directly the driving or retarding torque exerted by said unit in a direction to restore the force balance between said

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reference force and said tension proportional force.

5. A web tension control system as set forth in claim 4 including means for adjusting the magnitude of said reference force.

6. A web tension control system as set forth in claim 4 in which said means for regulating the pressure of the hydraulic fluid supplied to said hydraulic unit are set to maintain said pressure at a substantially constant preselected level.

7. A web tension control system as set forth in claim 4 in which said movement sensing means include means for varying the restriction on a continuous fluid flow through a first orifice in response to movement of said movable support means and sensing a change in fluid pressure at a second orifice resulting from the variation in flow restriction at said first orifice.

8. A web tension control system as set forth in claim 4 in which said variable displacement hydraulic unit is connected to operate as a pump in its normal mode of operation to control the retarding torque exerted on an unwinder roll; and

said system including means for automatically connecting said unit in a reverse flow configuration to cause operation thereof as a motor responsive to adjustment of the displacement of said unit into a motoring mode.

9. A web tension control system as set forth in claim 8 including means for limiting the maximum flow rate of hydraulic fluid through said hydraulic unit when connected in said motoring mode.

10. A web tension control system as set forth in claim 4 in which said displacement adjusting means are resiliently loaded in the direction of maximum unit displacement.

11. A web tension control system as set forth in claim 4 in which said guide roll means is supported substantially independently from the engagement thereof with said web to prevent the weight of said guide roll means from being imposed on said web.

12. A web tension control system as set forth in claim 7 in which the full range of movement of said movement sensing means is less than one tenth of one inch.

13. A web tension control system as set forth in claim 1 in which said tension error generating means includes means for varying the restriction on a continuous fluid flow through a first orifice in response to said tension proportional signal and sensing a change in fluid pressure at a second orifice resulting from the variation in flow restriction at said first orifice.

14. A web tension control system as set forth in claim 1 in which said variable displacement hydraulic unit is connected to operate as a pump in its normal mode of operation to control the retarding torque exerted on an unwinder roll; and

said system including means for automatically connecting said unit in a reverse flow configuration to cause operation thereof as a motor responsive to adjustment of the displacement said unit into a motoring mode.

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