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R. S. HAMBY

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TENSION CONTROLLED WEB DRIVE

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2 Sheets-Sheet 1

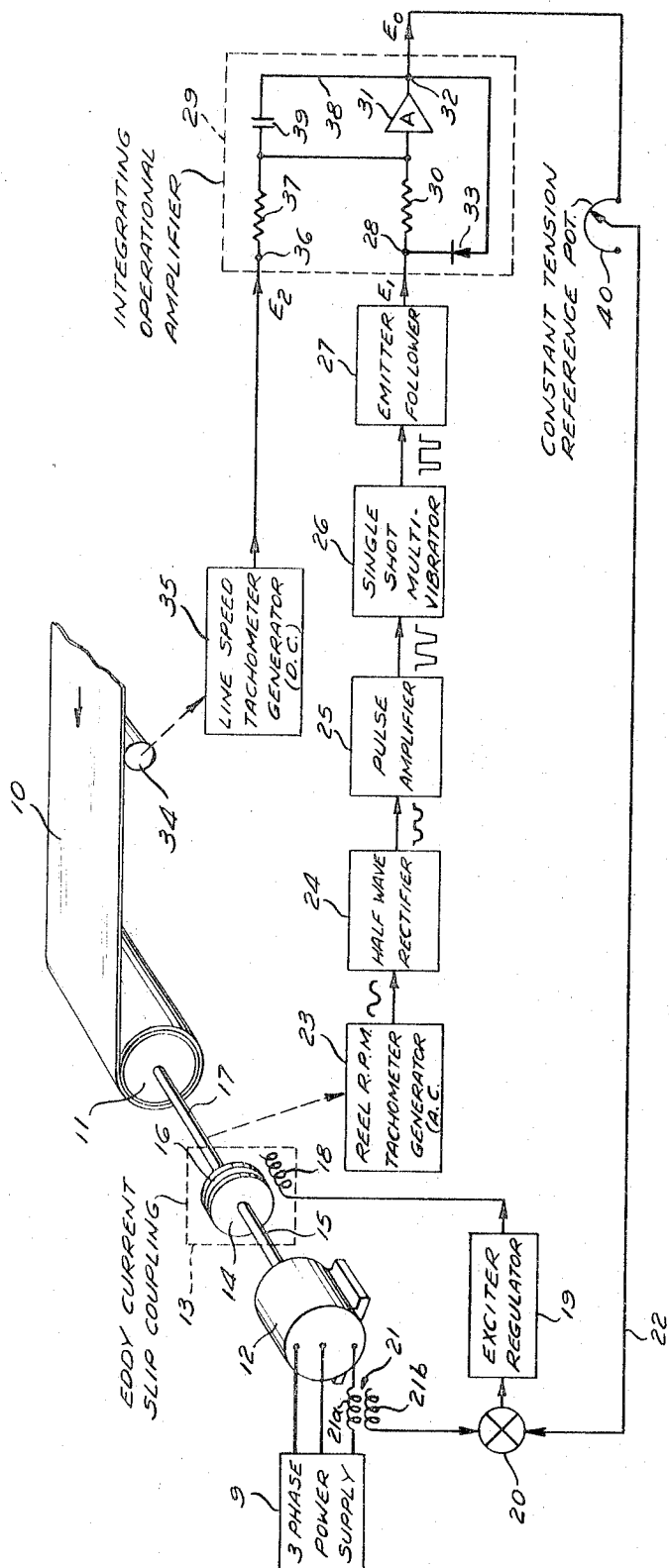


Fig. 1

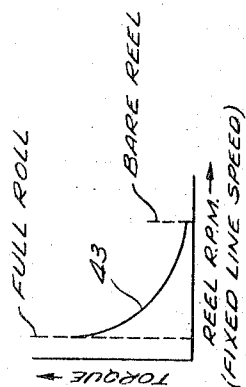


Fig. 2

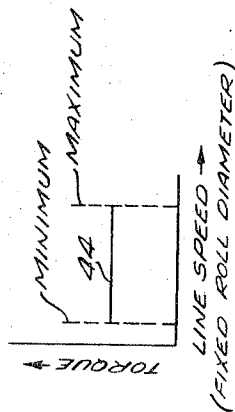


Fig. 3

INVENTOR.
RUSSELL S. HAMBY
BY Woodling, Krost,
Groner and Root
ATTORNEYS

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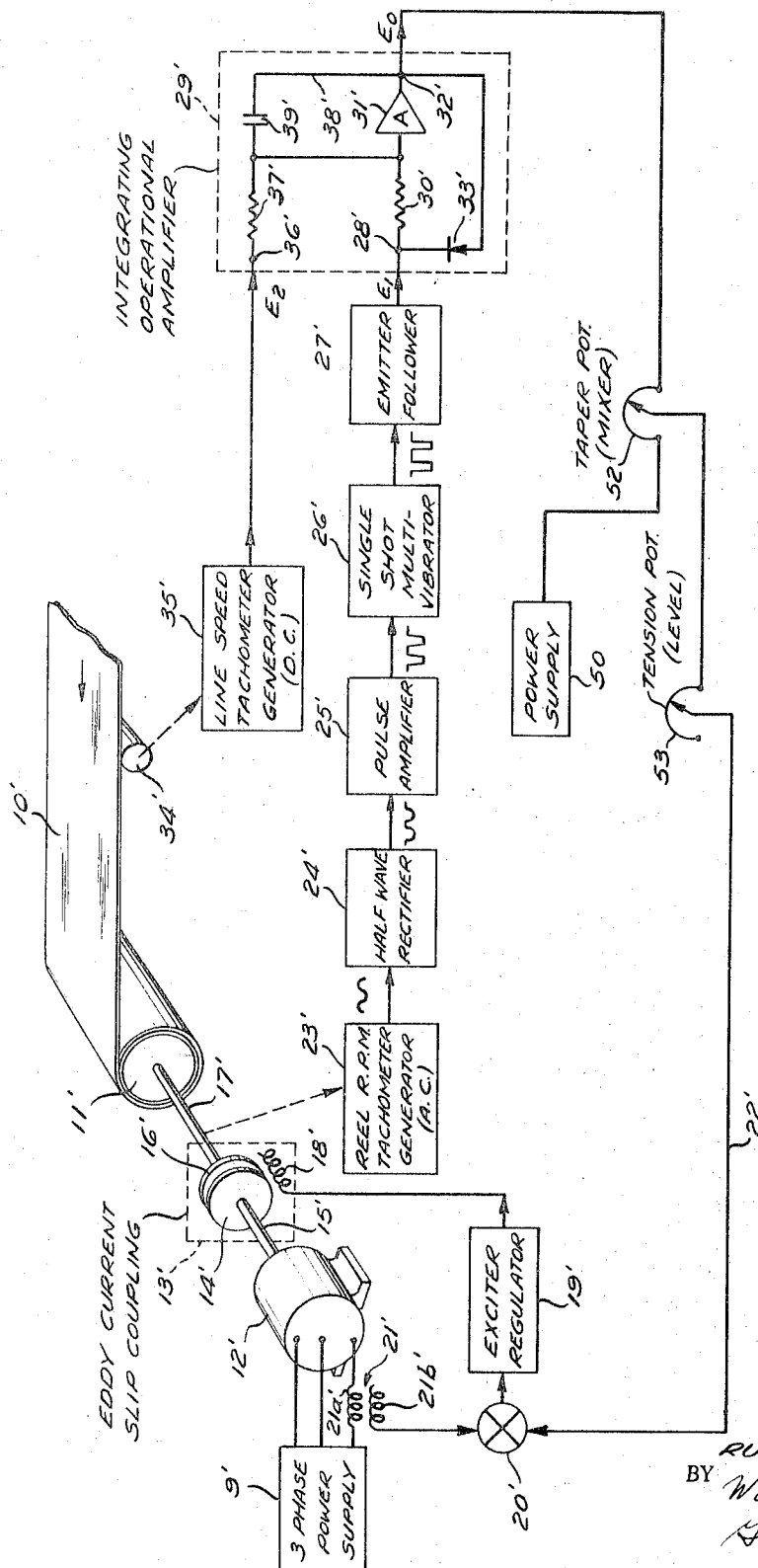
R. S. HAMBY

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2 Sheets-Sheet 2



INVENTOR.

RUSSELL S. HAMBY
BY Woodling, Knost,
Granger and Rust
ATTORNEYS

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TENSION CONTROLLED WEB DRIVE

Russell S. Hamby, Cleveland, Ohio, assignor to The Reliance Electric and Engineering Company, a corporation of Ohio

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13 Claims. (Cl. 318-6)

This invention relates to a control for regulating the tension on a flexible web which is being wound up on takeup reel or delivered from a pay off reel.

It is a principal object of this invention to provide a novel and improved control for this purpose.

It is also an object of this invention to provide such a control having a novel feedback arrangement for regulating the torque input to the takeup reel so as to regulate the tension on the web.

Another object of this invention is to provide such a control which is adapted to maintain constant tension on the web as it is being wound upon the reel.

Another object of this invention is to provide such a control which may be selectively adjusted by the user to provide constant tension or a desired gradually declining tension as the web is progressively wound up on the take-up reel.

Further objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram showing a constant tension control in accordance with the present invention;

FIGURE 2 shows reel torque plotted against reel speed in a reel drive system which maintains constant tension on the web at a fixed lineal speed of the web;

FIGURE 3 shows reel torque plotted against the lineal speed of the web in a reel drive system which maintains constant tension on the web at a fixed diameter of the web roll on the reel; and,

FIGURE 4 is a schematic diagram showing a control in accordance with the present invention which is adapted to provide constant tension on the web or a selected gradually declining tension as the web roll builds up on the reel.

Referring first to FIGURE 1, the control shown therein is arranged to maintain a uniform tension on a web 10 of flexible material which is being wound on a rotary take-up reel 11. The system may also be used on a system where a web is unwound from a pay off reel, since similar problems are involved, and thus where the expression is used that a web is wound on a reel it may be considered to include winding the web upon a reel or unwinding the web from the reel.

The reel 11 is driven by a variable speed, adjustable torque drive arrangement comprising a three-phase electric motor 12 and an eddy current slip-coupling 13 of known design. The input half 14 of this coupling is connected to the shaft 15 of motor 12. The output half 16 of the coupling is connected to the shaft 17 of the takeup reel.

The torque transmitted from the nominally constant speed motor 12 to the reel 11 by the eddy current slip-coupling 13 is determined by the magnitude of a torque control signal applied to a winding 18 in the slip coupling. This winding is energized by an exciter regulator 19. The arrangement of the exciter regulator 19 and the control winding 18 in the slip coupling is of known design and hence will not be described in detail.

The exciter regulator 19 is controlled by a mixer 20, which receives one input signal from a motor current sensing transformer 21.

This transformer includes a primary winding 21a, series-connected in one input line from the power supply 9

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to the drive motor 12, and a secondary winding 21b connected to one input to the mixer 20. Winding 21b, therefore, applies to the mixer 20 a torque feedback input signal whose amplitude is proportional to the current to motor 12. This input signal from winding 21b is proportional to the actual output torque of the eddy current slip-coupling 13 because in that coupling the torque at the output shaft 17 is simply transferred from the input shaft 15 driven by the motor 12, so that this output torque is proportional to the current to the motor. Therefore, the voltage developed across the secondary winding 21b of transformer 21 (corrected for power factor) will be proportional in amplitude to the torque which is actually delivered to the reel 11.

Mixer 20 has a second input signal from a feedback line 22, as described in detail hereinafter.

The output half 16 of the slip coupling 13 drives a reel r.p.m. tachometer generator 23, which produces an AC output signal whose frequency is proportional to the instantaneous rotational speed of the output half of the slip-coupling, which is the same as the speed of the take-up reel 11. This reel tachometer output signal is passed through a half wave rectifier 24 for negative half wave pulses and then through a pulse amplifier 25 in which the half wave sinusoidal envelope is amplified greatly. Preferably, the amplification in amplifier 25 is so great that the peak of the half-wave envelope is clipped off as relatively unimportant. The amplification which takes place in amplifier 25 makes it easy to determine precisely the timing of the rising wave front of the signal.

The output signal from the amplifier 25 is applied to the input of a single shot multivibrator 26. The multivibrator produces a train of substantially square wave pulses of negative polarity whose amplitude and width are substantially constant and whose frequency is proportional to the frequency of the reel tachometer generator output signal (and thus proportional to the rotational speed of takeup reel 11).

This train of output pulses from multivibrator 26 is passed through an emitter follower circuit 27, which acts as a buffer. The negative pulse output signal E₁, of the emitter follower is connected to one input terminal 28 of an integrating operational amplifier 29 of conventional design. In one practical embodiment, this operational amplifier has a high gain in the order of 100,000.

An input resistor 30 is connected between this input terminal 28 and the input side of a plurality of amplification stages designated generally by the reference numeral 31. These amplification stages invert the phase of the input signal as well as greatly amplifying them. The output terminal 32 of the amplification stages 31 is connected through a unidirectional current conducting device or clamping diode 33 to the input terminal 28.

An idler roller 34 is driven by the web 10 at a rotational speed determined by the linear speed of the web. This idler roller drives a line speed tachometer generator 35, which generates a positive polarity DC signal E₂, whose magnitude is proportional to the lineal speed of the web 10. This signal E₂ is applied to a second input terminal 36 of the integrating operational amplifier 29. An input resistor 37 is connected between this input terminal 36 and the input side of the amplification stages 31.

The amplifier also has a feedback loop 38, including a capacitor 39, connected from the output terminal 32 of its amplification stages 31 back to the input side of the latter.

In the operation of this amplifier, due to its input resistors 30 and 37 and its capacitive feedback, the amplifier produces an amplified output signal E₀, whose magnitude is proportional to the integrated difference between its line speed tachometer DC input signal E₂, and the input

pulses E_1 , derived from the reel r.p.m. tachometer generator 23. The line speed input signal E_2 is positive in sign, while the reel speed input pulses, E_1 , are negative. The amplifier inverts the phase of these input signals, so that the output signal E_0 will be negative in sign because E_2 exceeds E_1 in magnitude and E_0 will be proportional to the integrated difference between E_2 and E_1 , as expressed by the following equation:

$$E_0 = \frac{1}{RC} (\int E_2 - \int E_1) \quad (1)$$

Where R is the ohmic resistance of resistor 30 and C is the capacitance of capacitor 39, and assuming that the resistors 30 and 37 are of equal value.

The integral of E_1 over any period of time, T , is equal to the total area under all of the E_1 pulses applied to the amplifier input terminal 28 during that time. This area is a function of pulse width, pulse height and pulse frequency. Therefore

$$\int_0^T E_1 = (f)(T)(H)(W) \quad (2)$$

where f is the pulse frequency, T is the time period, H is the pulse height, and W is the pulse width.

The pulse width W is a constant which is determined by the characteristics of the single shot multivibrator 26.

The pulse height or amplitude H is determined by the magnitude of the output signal E_0 as follows:

The clamp diode 33 prevents the E_1 input pulses from becoming more negative than the amplifier output signal E_0 . If the negative height of the E_1 pulses at input terminal 28 were to tend to exceed the negative height of the DC output signal E_0 , then negative current would flow through the extremely low impedance path provided by the clamp diode 33 and would thereby equalize the negative potential at the input and output terminals 28 and 32 of the integrating operational amplifier 29. Therefore, the negative DC level of the amplifier output signal, E_0 , determines the height of the E_1 input pulses.

Therefore, substituting E_0 for H in Equation 2,

$$\int_0^T E_1 = (f)(T)(W)(E_0) \quad (3)$$

or

$$\int_0^T E_1 = \frac{(f)(W)(E_0)}{S} \quad (4)$$

where S is the Laplace operator.

The integral of the line speed input signal, E_2 , over the same period of time, T , is simply:

$$\int_0^T E_2 = E_2(T) = \frac{E_2}{S} \quad (5)$$

Substituting Equations 4 and 5 in Equation 1,

$$E_0 = \left(\frac{E_2}{S} - \frac{E_0 f W}{S} \right) \frac{1}{RC} \quad (6)$$

or

$$E_0 = \frac{E_2}{fW \left(1 + \frac{RCS}{fW} \right)} \quad (7)$$

Equation 7 states that the amplifier output signal, E_0 , is a function of the ratio of the line speed (which determines the magnitude of E_2) to the reel speed (which determines the magnitude of f). The term RC/fW is a time constant for input changes.

As expressed by Equation 7 the magnitude of the output signal E_0 is directly proportional to the line speed. The magnitude of the output signal, E_0 , is an inverse function of the rotational speed of the reel.

The amplifier output signal E_0 is fed back through a constant tension reference potentiometer 40 and feedback loop 22 to the mixer 20 as a feedback signal for regulating the torque control signal applied to the control winding 18 in the eddy current slip-coupling 13. The

mixer 20 compares this feedback signal against the motor current feedback signal from the current transformer 21 and produces an output signal which controls the amplitude of the torque control signal which the exciter regulator 19 applies to the control winding 13. The setting of the reference potentiometer 40 determines the web tension which this control is to provide.

FIGURE 2 illustrates the hyperbolic curve 43 of torque on the reel versus rotational speed of the reel which is required to provide constant tension on the web for a fixed lineal speed of the web. When the reel 11 is bare, the torque required to drive the reel is a minimum since this torque depends only upon the weight of the reel and the web rolled thereon. As winding proceeds, the weight of the reel and the web roll thereon increases to increase the lever arm, and consequently the output torque of the slip coupling 13 must increase in order to maintain constant tension on the web. Also, the rotational speed of the reel must decrease as the web is wound up on the reel, in order to maintain constant tension and uniform lineal speed of the web.

FIGURE 3 illustrates the curve 44 of reel torque versus lineal speed of the web for a given roll diameter on the reel which is required for constant tension on the web. As indicated by this curve 44, the reel torque should be constant for changes in the line speed of the web. This is because the torque necessary to produce a given tension on the web depends only upon the weight of the reel and the web roll thereon. Therefore, if the lineal speed of the web happens to change abruptly, the torque on the reel should remain unchanged, even though the rotational speed of the reel will change in accordance with the change in line speed.

The torque control signal applied to winding 18 in the slip-coupling is determined conjointly by the motor current feedback signal from transformer 21, which is effectively a torque feedback signal, applied to one input of mixer 20, and the reference feedback signal on line 22. In the absence of a change in this reference feedback signal on line 22, this torque control signal on winding 18 would remain constant. Accordingly, the eddy current slip-coupling would have a constant torque and decreasing taper tension.

As already explained, as the reel 11 winds up the web, the feedback signal on line 22 will change in accordance with the line speed and the reel speed, being directly proportional to the line speed and inversely proportional to the reel speed. Therefore, the torque control signal applied to winding 18 will change so as to regulate the output torque of the slip-coupling to provide a performance curve 43 as shown in FIGURE 2, thereby maintaining constant tension on the web during the build-up of the web roll on the reel and despite any fluctuations which may take place in the line speed.

The present control satisfies both of these requirements for maintaining constant tension on the web.

The formulas show that the output voltage is the quotient of the line speed divided by the reel speed. Further, the formulas show that this amounts to a subtraction of the integrals of two voltages, namely, the integral of the line voltage minus the integral of a voltage which is a function of the reel speed signal. This function of the reel speed signal results from modifying the pulse train from the reel tachometer by the output voltage of the amplifier. The voltage E_1 represents the reel speed only in the frequency generated by the AC tachometer 23. However, the pulse width is a constant determined by the multivibrator 26 and amplitude of the pulse is dependent upon the output voltage of the amplifier. This is why the voltage E_1 is modified and is not the same as the voltage from the AC tachometer 23. The particular circuit of the integrating operational amplifier 29 performs this function of Equation 7, namely, dividing the line voltage by a signal proportional to reel frequency and hence reel speed. It is this quotient or output voltage E_0 which is

used for control of the exciter regulator 19 to maintain a constant or controlled tension in the web 10.

For a given line speed, as the web roll builds up on the take-up reel, the rotational speed of the reel will tend to decrease. This will reduce the frequency of the E_1 input pulses to the integrating operational amplifier, so that the latter's output signal, E_0 , will increase in magnitude. This signal is fed back via line 22 to the mixer 20, producing an error signal which causes the exciter regulator 19 to change the energization of control winding 18 so as to increase the torque output of the slip coupling 13. This torque increase will be reflected as an increase in the current to the drive motor 12, so that the torque reference signal from the transformer 21 will increase in magnitude to balance the feedback signal on line 22 when the correct torque is reached. Therefore, throughout the build-up of the web on the reel, the continuous comparison between the torque feedback signal from transformer 21 and the reference feedback signal on line 22 will automatically increase the torque output of the slip-coupling 13 substantially in accordance with the curve 43 shown in FIGURE 2.

If the line speed changes abruptly (at a given diameter of the reel and the web roll thereon), this would increase the magnitude of the E_2 input signal to the integrating operational amplifier 29, which would tend to increase the output signal, E_0 , of the amplifier. However, for the particular output torque of the slip-coupling 13 then prevailing (depending upon the diameter of the reel and the web roll thereon), this increase in the line speed would also increase the rotational speed of the reel. The frequency of the E_1 input pulses to the amplifier would increase, thereby tending to decrease the magnitude of the E_0 output signal from the amplifier. The net effect of the increase in both the E_2 and E_1 input signals is that they substantially cancel one another and the E_0 output signal remains unchanged. Therefore, for a given diameter of the reel and the web roll thereon, an abrupt increase in the line speed will not change the torque output of the slip coupling 13, which satisfies the performance curve of FIGURE 3.

The same is true of any sudden decrease in the line speed, which would decrease the magnitude of the E_1 and E_2 signals such that the amplifier output signal, E_0 , would remain unchanged.

For some practical applications, it may be preferable to regulate the web tension so as to provide a controlled tension which decreases gradually (instead of remaining constant) as the web roll builds up on the reel. For this purpose the modified control shown in FIGURE 4 may be employed.

The FIGURE 4 circuit is the same as that of FIGURE 1, with like components having the same reference numerals with a "prime" subscript added, except for the addition of a power supply 50 and potentiometers 52 and 53, all associated with the feedback line 22' from the output of the integrating operational amplifier 29' to the mixer 20' and the deletion of potentiometer 40.

The power supply 50 is connected to one end of potentiometer 52, which is called a "taper potentiometer (mixer)." The output terminal 32' of amplifier 29' is connected to the opposite end of potentiometer 52. The adjustable contact of potentiometer 52 is connected to one end of potentiometer 53, called the "tension potentiometer (level)."

The power supply 50 applies a reference voltage to one end of potentiometer 52. Potentiometer 52 acts as a mixer which compares this reference voltage against the constant tension reference signal from amplifier 29'. The output signal from this mixer is passed through potentiometer 53 to the feedback line 22' leading to mixer 20. By adjusting the mixer 52, the control can be adjusted throughout the range from a constant tension setting (with the slider of 52 all the way to right) to a constant torque setting (with the slider of 52 all the way to the left).

With constant torque applied to the reel 11' and with reel build-up increasing the lever arm thereof, the tension on the web 10' will be gradually reduced for taper tensioning. Except at the constant tension setting, this control provides a tension on the web which gradually declines as the web is wound up on the take-up reel. Accordingly, this may be termed a "taper tension" control. The "taper" (i.e., the progressive reduction in web tension) increases as the slider of mixer 52 is adjusted toward the left in FIGURE 4.

In other respects, the control of FIGURE 4 is essentially similar in operation to that of FIGURE 1, and a detailed description of their common operating characteristics will not be repeated.

To achieve an understanding of the operation of the circuit of FIGURE 4, it is best to first consider an operation of the circuit of FIGURE 1, from which this FIGURE 4 is derived. FIGURE 1 is a constant tension circuit and FIGURE 4 permits a taper or gradually reducing tension. Very briefly and as described above, the constant tension circuit of FIGURE 1 operates as follows:

- (a) The reel diameter builds up,
- (b) The lever arm thereof increases,
- (c) More torque on the reel is required,
- (d) More power to the clutch winding 18 is required, and as the reel builds up,
- (e) The speed of reel 17 decreases,
- (f) The frequency output of tachometer 23 decreases,
- (g) There is an increased output E_0 and on line 22,
- (h) This acts through regulator 19 for increased energization of clutch winding 18 so that torque is increased, and
- (i) The tension in web 10 is maintained constant.

Now in FIGURE 4 what has been added is essentially the power supply 50 and the taper potentiometer or mixer 52. Assume first that the movable blade of potentiometer 52 is moved completely to the right, then this is the constant tension setting and the operation of the circuit is identical to that described for FIGURE 1. This is because the potentiometer 52 is getting its entire voltage from E_0 and none from the power supply 50 so it is just as if the power supply 50 were not in the circuit. One would again have an increasing torque with increasing reel build-up to maintain constant tension.

Conversely, if the movable blade of potentiometer 52 were moved completely to the left, then this would be the constant torque setting. In such case, the movable blade of potentiometer 52 would be picking up a constant voltage from power supply 50 and it would be just as if the entire feedback loop from tachometers 23 and 35 were completely eliminated from the circuit. This would then be a fixed voltage supplied along the reference feedback line 22'. This would result in a constant torque and constant torque would give a decreasing web tension as the reel builds up.

By setting the movable blade of the potentiometer 52 at some intermediate point, one can select the desired proportion of constant tension versus constant torque, in other words, the desired rate of decrease of the tension.

The tension potentiometer 53 sets the desired level of tension in the web 10'. For example, one pound force or ten pounds force on the web is selected by fixing the potentiometer 53 at different settings. Neither potentiometer 52 nor 53 is varied during operation in order to obtain the constant or taper tension, they are left at predetermined settings.

While certain presently-preferred embodiments of this invention have been described and illustrated, it is to be understood that the invention is susceptible of other embodiments and that various modifications, omissions and refinements which depart from the disclosed embodiments may be adopted without departing from the spirit and scope of this invention. For example, the eddy current slip-coupling may be replaced by an armature-controlled

DC drive or any other appropriate drive arrangement which may be controlled in torque output.

What is claimed is:

1. A control for regulating the tension on a web wound on a rotatable reel comprising, a variable speed arrangement for the reel, said variable speed arrangement having a normally constant torque,
 - means for sensing the torque of said variable speed arrangement,
 - means for generating a reel speed signal,
 - means for generating a line speed signal,
 - an integrating operational amplifier, means applying said reel speed signal and said line speed signal to said integrating operational amplifier of opposite polarity for obtaining a control signal directly proportional to said line speed signal and inversely proportional to said reel speed signal,
 - and means responsive to said torque sensing means and responsive to said control signal for regulating the torque of said variable speed arrangement.
2. A control for regulating the tension on a web wound on a rotatable reel comprising,
 - a variable speed arrangement for the reel, said variable speed arrangement having means for normally maintaining a substantially constant torque,
 - means for sensing the torque of said variable speed arrangement,
 - means for sensing the rotational speed of the reel for generating a reel speed signal,
 - means for sensing the lineal speed of the web for generating a line speed signal,
 - an integrating operational amplifier, means applying said reel speed signal and said line speed signal in opposite polarity to different inputs of said integrating operational amplifier for obtaining an output signal directly proportional to said line speed signal and inversely proportional to said reel speed signal,
 - and means responsive to said torque sensing means and output signal for regulating the torque of said variable speed arrangement.
3. The control of claim 2, wherein said last-mentioned means regulates the torque to maintain a substantially constant tension on the web.
4. The control of claim 2, wherein said last-mentioned means includes a predetermined reference voltage and regulates the torque to provide a tension on the web which is reduced progressively as the web is wound on the reel.
5. A control for regulating the tension on a web being wound on a rotatable reel comprising:
 - a variable speed drive arrangement for rotating the reel, said drive arrangement having means for normally maintaining a substantially constant output torque,
 - means associated with said drive arrangement for producing a torque feedback signal proportional to the output torque of said drive arrangement,
 - means responsive to the rotational speed of the reel for generating a reel speed signal of one polarity,
 - means responsive to the lineal speed of the web for generating a line speed signal of the opposite polarity,
 - an integrating operational amplifier,
 - means for applying said reel speed signal and said line speed signal as opposite polarity input signals to the amplifier,
 - said amplifier including means for producing an output signal which varies inversely with said reel speed signal and which varies directly with said line speed signal,
 - and means responsive to both said torque feedback signal and said amplifier output signal for regulating the speed and torque of said drive arrangement.
6. The control of claim 5 wherein:
 - there is provided clamp diode means connected across said integrating operational amplifier and operative

to limit the amplitude of said reel speed input signal thereto in accordance with the magnitude of the output signal of said integrating operational amplifier.

7. A control for regulating the tension on a web being wound on a rotatable reel comprising:
 - a variable speed drive arrangement for rotating the reel, said drive arrangement having means for normally maintaining a substantially constant output torque,
 - means associated with said drive arrangement for producing a torque feedback signal proportional to the output torque of said drive arrangement,
 - means responsive to the rotational speed of the reel for generating a reel speed signal,
 - means responsive to the lineal speed of the web for generating a line speed signal,
 - means connecting an integrating operational amplifier, said reel speed signal and said line speed signal in opposite polarities to said integrating operational amplifier for generating a reference feedback signal therefrom which varies inversely with said reel speed signal and which varies directly with said line speed signal,
 - a mixer,
 - means for applying said torque feedback signal and said reference feedback signal as input signals to said mixer to be compared therein,
 - and means responsive to the output signal from the mixer for regulating the speed and torque of said drive arrangement.
8. The control of claim 7 wherein:
 - said means for generating the reel speed signal comprises a reel tachometer generator driven by said drive arrangement to generate an AC signal whose frequency is proportional to the rotational speed of the reel, a half-wave rectifier coupled to the output of said reel tachometer generator, a pulse amplifier coupled to the output of said rectifier, and a single shot multivibrator coupled to the output of said amplifier for producing a train of uniform width pulses whose frequency is proportional to the rotational speed of the reel,
 - said means for generating the line speed signal is a line speed tachometer operable to produce a DC signal proportional to the lineal speed of the web,
 - said integrating operational amplifier includes means for producing a DC output signal of said one polarity whose magnitude is proportional to the integrated difference between said line speed and reel speed input signals,
 - and wherein there is provided clamp diode means connected across said integrating operational amplifier and operative to limit the pulse amplitude of said reel speed signal in accordance with the magnitude of the output signal of said integrating operational amplifier.
9. The control of claim 7 wherein there is provided a feedback circuit connected between the output of said integrating operational amplifier and said mixer, said feedback circuit including a constant tension reference potentiometer which is adjustable to set a predetermined constant tension for the web.
10. The control of claim 7 wherein there is provided a feedback circuit connected between the output of said integrating operational amplifier and said mixer, a power supply, said feedback circuit including a mixer potentiometer connected between said power supply and the output of said amplifier, said mixer potentiometer being adjustable to selectively determine the rate at which the output torque of said drive arrangement is reduced as the web is wound up on the reel.
11. A control for regulating the tension on a web extending to a rotatable reel with a variable plurality of layers of web thereon comprising:
 - a variable speed arrangement for the reel,
 - means for generating a reel speed signal of one polar-

ity including a reel tachometer generator driven in accordance with the speed of said reel to generate an AC signal whose frequency is proportional to the rotational speed of the reel,

a line speed tachometer operative to produce a DC line speed signal of the opposite polarity whose magnitude is proportional to the lineal speed of the web,

an integrating operational amplifier having a high gain, first and second inputs and an output,

means for applying said reel speed signal of said one polarity to said first input of said integrating operational amplifier,

means for applying said line speed signal of said opposite polarity to said second input of said integrating operational amplifier,

unidirectional current conducting means connected between said output and said first input of said operational amplifier for limiting the amplitude of said reel speed input in accordance with the magnitude of the output signal from said operational amplifier,

and a feedback circuit connected between the output of said integrating operational amplifier and said variable speed arrangement.

12. A control for regulating the tension on a web wound on a rotatable reel comprising:

a variable speed arrangement for the reel,

means for generating a reel speed signal of one polarity including a reel tachometer generator driven by said reel to generate an AC signal whose frequency is proportional to the rotational speed of the reel, a half-wave rectifier coupled to the output of said reel tachometer generator, a pulse amplifier coupled to the output of said rectifier, and a single shot multivibrator coupled to the output of said amplifier for producing a train of uniform width pulses whose frequency is proportional to the rotational speed of the reel,

a line speed tachometer operative to produce a DC line speed signal of the opposite polarity whose magnitude is proportional to the lineal speed of the web,

an integrating operational amplifier having an amplification stage, a first input terminal, first resistance means connected between said first input terminal and the input side of said amplification stage, a second input terminal, second resistance means connected between said second input terminal and said input side of said amplification stage, and a feedback loop including capacitance means connected between the output and input sides of said amplification stage,

means for applying said reel speed signal pulses of said one polarity to said first input terminal of the integrating operational amplifier,

means for applying said line speed signal of said opposite polarity to said second input terminal of the integrating operational amplifier,

clamp diode means connected between said first input terminal and the output side of said amplification stage for limiting the amplitude of said reel speed input pulses in accordance with the magnitude of the output signal from said amplification stage,

and a feedback circuit connected between the output of said integrating operational amplifier and said variable speed arrangement.

13. A control for regulating the tension on a web being wound on a rotatable reel comprising:

a variable speed drive arrangement for the reel includ-

ing an AC motor and an eddy current slip-coupling driven by said motor and having its output coupled to the reel,

a current sensing transformer connected to sense the current to said motor so as to produce a feedback signal which is proportional to the output torque of said slip-coupling,

means for generating a reel speed signal of one polarity including a reel tachometer generator driven by said drive arrangement to generate an AC signal whose frequency is proportional to the rotational speed of the reel, a half-wave rectifier coupled to the output of said reel tachometer generator, a pulse amplifier coupled to the output of said rectifier, and a single shot multivibrator coupled to the output of said amplifier for producing a train of uniform width pulses whose frequency is proportional to the rotational speed of the reel,

a line speed tachometer operative to produce a DC line speed signal of the opposite polarity whose magnitude is proportional to the lineal speed of the web,

an integrating operational amplifier having an amplification stage, a first input terminal, first resistance means connected between said first input terminal and the input side of said amplification stage, a second input terminal, second resistance means connected between said second input terminal and said input side of said amplification stage, and a feedback loop including capacitance means connected between the output and input sides of said amplification stage,

means for applying said reel speed signal pulses of said one polarity to said first input terminal of the integrating operational amplifier,

means for applying said line speed signal of said opposite polarity to said second input terminal of the integrating operational amplifier,

clamp diode means connected between said first input terminal and the output side of said amplification stage for limiting the amplitude of said reel speed input pulses in accordance with the magnitude of the output signal from said amplification stage,

a mixer,

means for applying said torque feedback signal as a first input signal to said mixer,

a feedback circuit connected between the output side of said amplification stage in the integrating operational amplifier and said mixer for applying a reference feedback signal as a second input signal to said mixer, said feedback circuit including potentiometer means for determining the tension to be applied to the web as the latter is wound up on the reel,

a control winding for said slip-coupling controlling the speed and torque of said coupling in accordance with the energization of the control winding,

and an exciter regulator connected between said mixer and said control winding for energizing the latter in accordance with the output signal from the mixer.

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