WINDING AND UNWINDING CONTROLS

Filed Dec. 19, 1955 2 Sheets-Sheet 1

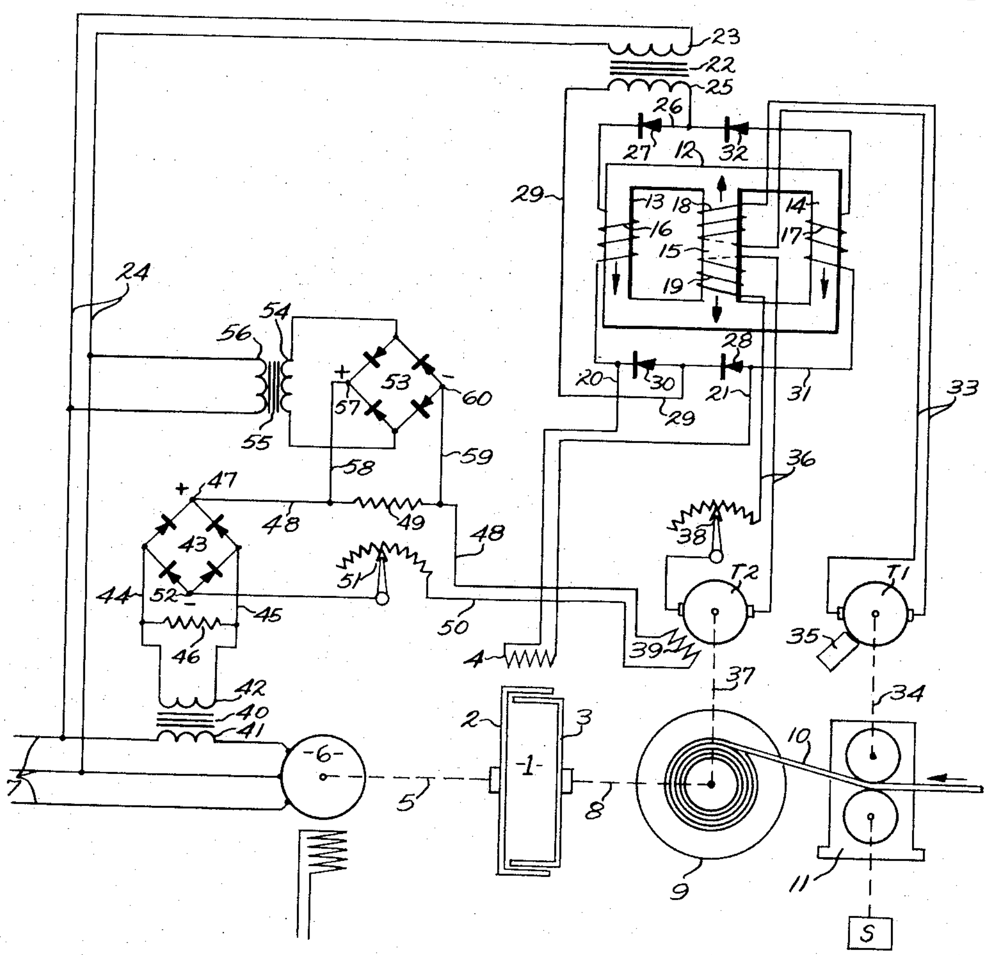

Fig. 1

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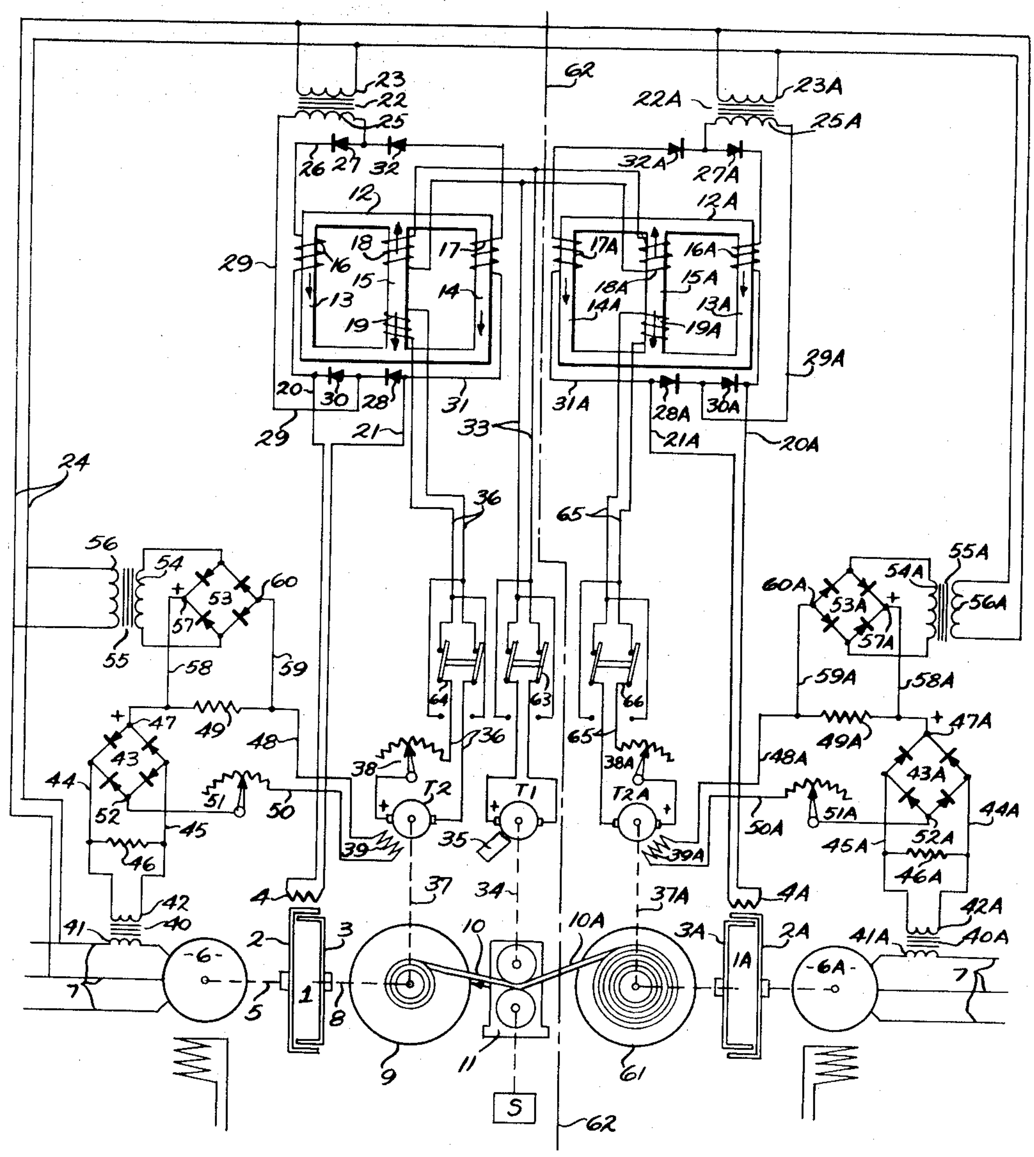

Fig. 2

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WINDING AND UNWINDING CONTROLS

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23 Claims. (Cl. 242—75.51)

This invention relates to subject matter classified as winding and reeling.

In the various arts, strip material, wire etc., is wound on, or unwound from, a reel or the like; and hereinafter, for convenience, the material will be referred to, generally, as in the form of strip.

When strip is being wound on a reel, it often comes to the reel at constant linear speed; or when being unwound, leaves the reel at constant linear speed.

The constant speed of the strip in such cases is variously predetermined, for example, by a strip processing apparatus through which the strip passes.

For well known reasons, it is desirable, or even necessary, in practice, to maintain constant tension in the strip as it is wound on, or as it is unwound from the reel.

The reel when winding the strip is therefore usually driven by motor power and the torque thus applied to the reel pulls forwardly on the strip, and puts it under tension; or in the case when the strip is being unwound from the reel, the reel is rotated in the unwinding direction by the strip and motor torque is applied to the reel to oppose the unwinding rotation to put tension in the strip.

As the strip winds on or unwinds from the reel, the diameter of the roll of strip on the reel increases or decreases, respectively.

To maintain the tension constant as aforesaid, the torque applied to the reel is therefore gradually increased or decreased respectively. The present invention relates to apparatus and controls of this general type.

While, in many cases, winding or unwinding of the strip goes on when, as referred to above, the strip has a predetermined constant linear speed. But there are instances in which the constant speed may have different values at different times; or may be adjusted from one constant linear speed to another; or in which the linear speed may even vary while winding or unwinding is going on.

To control the torque applied to the reel for the aforesaid purposes, presents a problem; and various control schemes have been proposed to solve the problem; but such schemes have not been satisfactory, among the reasons being that they do not control the tension in the strip with sufficient sensitivity as winding or unwinding goes on; and involve numerous moving parts, contactor contacts etc. to effect the regulation of the torque applied to the reel by the motor.

One of the objects of the present invention is to provide a control that solves the aforesaid problem in an improved manner, and obviates objections to prior controls, some of which are mentioned above.

While the invention may be used to wind or unwind strip of various kinds, in connection with various means for causing the strip to be at a given constant linear speed or at adjustable constant speed, or at variable speed, one important use is to wind or unwind metal strip, when the speed of the strip is determined by driven mill rolls which concurrently roll the strip to a desired thickness; and in order to describe herein at least one use of the invention as required by law it will be described herein as applied to such use, as an illustrative example.

Two embodiments of the invention are fully described hereinafter.

In one embodiment, the strip comes from the mill rolls, and is wound upon a reel at constant tension.

In the other embodiment, the strip comes from a wound reel, passes through the mill rolls, and is then wound on another reel, the strip tension being maintained constant at each side of the mill rolls.

In either embodiment it is to be understood that the mill rolls may have a fixed constant speed, or adjustable constant speed, or variable speed; and correspondingly control the speed of the strip.

The first embodiment, in the form described hereinafter as an illustrative example, comprises the following; the actual invention being that set forth in the appended claims.

An electric motor drives the input element of a slipping clutch of the eddy current type, and the output element of the clutch drives the reel.

The clutch has an energizing winding and transmits variable torque from the motor to the reel as the energization is varied.

The output of a magnetic amplifier energizes the clutch winding, the output being controlled by a first and a second control winding of the amplifier mutually opposed.

The first control winding is energized by the output of a first D.C. generator, driven at speed proportional to the speed of the mill rolls and therefore is energized proportionally to the linear speed of the strip.

The second control winding is energized by the output of a second D.C. generator driven at the speed of the reel, and which has a field winding energized proportionally to the current taken by the clutch driving motor.

The current taken by the driving motor is a measure of the torque transmitted to the reel. The second generator therefore energizes the second control winding proportionally to the winding torque on the reel; while concurrently energizing it proportionally to the speed of the reel.

The second control winding is thus energized proportionally to the product of reel speed and torque.

The first control winding is wound so as to tend to increase the amplifier output; and the second control winding by opposing the first one, tends to decrease the amplifier output; and therefore the amplifier energizes the clutch winding proportionally to their difference.

At any instant, the reel has a certain speed determined by the instant speed of the strip; and the second generator energizes the second control winding at a certain value, corresponding to the instant speed of the reel.

The amplifier output energizes the clutch winding, and motor torque is applied by the clutch to the reel, putting the strip under tension.

As the winding goes on, the diameter of the strip on the reel increases and causes the speed of the reel to decrease. This speed change is reflected in the output of the second generator which causes the amplifier to increase its output, increasing the torque transmitted by the clutch to the reel to maintain the tension in the strip constant.

Adjustment means are also provided to change the tension in the strip as it is being wound on the reel.

The second embodiment of the invention, in the form fully described hereinafter, which is again an illustrative example, is as follows: the actual invention again being that set forth in the claims.

The strip comes from the mill rolls and is wound on a reel, and the tension in the strip is maintained constant as in the first embodiment.

Here the strip goes to the mill rolls from a reel on which it has previously been wound, and from which it unwinds.

Torque is applied to the unwinding reel from the output element of a slipping eddy current clutch and the input element of the clutch is driven by an electric motor. The reel is rotated by the strip drawn therefrom in the unwinding direction and the clutch torque on the reel is in the winding direction and yieldingly opposes its rotation, and this puts tension in the strip.

The clutch-torque, applied to the unwinding reel, is determined by energization of a clutch winding.

A control similar to that of the first embodiment, responsive to both the speed of the unwinding reel and the torque thereon, is utilized to maintain the tension constant in the strip between the unwinding reel and the mill rolls.

The unwinding tension in the strip on one side of the mill rolls is adjustable, and may be adjusted to be the same as or different from that of the winding tension on the other side.

In this second embodiment, the mill rolls may be reversed, and the strip passed therthrough in the reverse direction for a second rolling operation and the unwinding and winding reels then become, respectively, the winding and unwinding reels.

Further objects of the invention are to provide:

A control for a winding reel, or an unwinding reel, or for both an unwinding and a winding reel having the features, singly or in combination, described in the foregoing general description of the embodiments of the invention.

Other objects will become apparent hereinafter to those skilled in the art to which the invention appertains.

The invention is fully disclosed in the following description taken in connection with the accompanying drawing in which:

Fig. 1 is a diagrammatic view, illustrating the invention as applied to the winding of strip on a reel as it comes from the rolls of a strip rolling mill; and,

Fig. 2 is a diagrammatic view illustrating the invention as applied to the unwinding of strip from one reel as it goes to the rolls of a strip rolling mill and winding the strip on another reel as it comes from the mill rolls.

Winding

Referring to Fig. 1 of the drawing there is shown at **1** a slipping clutch, which may be of any known or suitable type, but which in the present invention is preferably an electrodynamic or eddy current clutch, as indicated, symbolically, in the drawing.

The clutch as shown comprises a rotary torque input element **2**, and a rotary torque ouput element **3**, and an electric field winding **4** for variably energizing the clutch, to vary the output torque.

The input element **2** is connected as indicated by the line **5**, to a motor **6**.

This motor, for purposes of the present description is a constant speed synchronous motor as indicated symbolically, and in some cases such a motor will be used. In other cases an induction motor, for example a three phase motor will be used as will be referred to. The motor **6** is supplied with three phase current from mains **7**; and the input clutch element **2** is driven at constant speed thereby.

The output element **3** is connected as indicated by the line **8**, to a rotary strip winding reel **9** and drives it.

The clutch **1** is one having such characteristics that when the input element **2** is driven at a predetermined speed, then for any given degree of energization of its winding **4**, it will transmit a corresponding constant torque, regardless of the speed of the output element **3** and the degree of slip between the elements.

Also clutch will transmit the same torque for the same degree of winding energization if the speed of the input element varies within a certain range of speed. Commercial clutches are known having such characteristics, at least within a range of energization and a range of input element speed suitable for the purposes hereof and such a clutch is chosen.

Strip **10** winds on the driven reel **9**, coming from a strip processing apparatus, exemplified herein by mill rolls **11**, rolling the strip to a desired thickness. The rolls will ordinarily be driven at constant speed by means indicated symbolically at S, and will be so considered, and the strip will be considered as having a corresponding constant speed.

At **12**, generally, is a magnetic amplifier comprising a core having outer legs **13—14** and a middle leg **15**.

The outer legs **13—14** have main windings **16—17** thereon; and the middle leg has two control windings **18—19** thereon. The arrangement of the core and windings here described is not essential, but is utilized for simplicity of description, and may be variously modified by those skilled in the art.

The amplifier **12** has input energization from the alternating current mains **7**, and supplies unidirectional output current to output mains **20—21**, by the following means and amplifier action.

A transformer **22** has its primary **23** energized from the A.C. mains **7** by wires **24**.

The transformer secondary **25** is connected at its right end to a wire **26**, and half waves of current in one alternating direction flow from said end of the secondary, through a rectifier **27**, thence through main winding **16** to output main **20**; thence through a load which is the said winding **4** of the clutch **1**; and thence back to output main **21**; thence through a rectifier **28** to a wire **29** to the left end of the secondary **25**.

Half waves of current in the other alternating direction flow from the left end of the secondary **25**, by wire **29**, through a rectifier **30** to output main **20**, through the load **4** and back by output main **21**, thence by wire **31**, through main winding **17**, through a rectifier **32** to the right end of the secondary **25**.

The half waves of current in the windings **16—17** cause them to produce unidirectional magnetic flux in the core versed, and the strip passed therethrough in the reverse windings.

The value of the half waves of current going to the clutch winding **4** and the value of the flux, will be determined by the reactance of the main windings **16—17**.

The control windings **18—19** when energized with unidirectional current as will be described, vary the flux quantitatively and thereby vary the reactance of the main windings **16—17**, and therefore vary the current in the winding **4**.

The main windings **16—17** are designed in a manner well known to those skilled in the art, so that, when considered alone, they have such reactance that the magnetic flux in the legs **13—14** will, in general, be near the knee of their saturation curves; and, in consequence, the value of the flux and, correspondingly, the value of current to the winding **4**, will change very sensitively with changes of current in the control windings **18—19** and with great amplification.

The control winding **18** is energized through lines **33**, by a direct current generator **T1**, driven by the mill rolls **11** as indicated by the line **34**, and at constant speed proportional thereto; and delivers direct current to the winding **18** proportional to its speed, by virtue of a constant field, which for convenience may be a permanent magnet field as shown at **35**; and as will be apparent it energizes the control winding **18** proportionally to the speed of the strip **10**. The direction of the magnetomotive force of the winding **18** is indicated by the arrow at the winding.

The control winding 19 is energized with direct current through lines 36, by a direct current generator T2 driven by the reel 9 as indicated by the line 37 and at speed proportional thereto. The energizing current to the winding 19 is rendered adjustable by a manual rheostat 38.

The direction of the magnetomotive force of the winding 19 is indicated by the arrow at the winding. The winding 19 thus opposes the winding 18.

Energization of the winding 18 tends to cause the amplifier to deliver more output; and energization of the winding 19 tends to reduce the effectiveness of the winding 18 to thereby reduce the output.

The generator T2 has a field winding 39; variably energizable as will be described. As will be apparent the control winding 19 will be variably energized in accordance with variations of energization of the field winding 39, and in accordance with variations of the speed of the reel 9.

A current transformer 40 has a primary 41 in series with one of the mains 7 going to the motor 6; and its secondary 42 supplies input current to a polygonal rectifier loop 43 by wires 44—45.

A resistor 46 bridges the input wires 44—45, by which the value of current to the rectifier 43 may be predetermined or controlled.

A point 47 on the rectifier 43 may be considered as positive, and rectified current therefrom goes by a wire 48 through a resistor 49 of fixed preselected ohmic value, to the field winding 39 of the generator T2 and back by wire 50 through a manually adjustable rheostat 51, to a negative point 52 on the rectifier.

A polygonal rectifier loop 53 has alternating current input from the secondary 54 of a transformer 55, whose primary 56 is connected to the alternating current mains 7 by the wires 24. A point 57 on the rectifier 53 may be considered as positive and rectified current flows therefrom by a wire 58, to the wire 48, through resistor 49 to a wire 59 and back to a negative point 60 on the rectifier.

From the foregoing it will be apparent that the current from the rectifier 53 is of constant value and that it will produce a drop of potential of constant value in the resistor 49, in opposition to the current in the wire 48 and reduce the current tending to flow therein by a predetermined amount, and this is for the following purpose.

From the foregoing it will be seen that, through the agency of the transformer 40, and the rectifier 43, the field winding 39 tends to be energized proportionally to the current taken by the motor 6.

The whole current taken by the motor 6 may be considered as comprising two components. One component produces motor torque that keeps the rotating parts of the motor and the clutch 1, and the reel 9, rotating, by overcoming friction etc. and may be considered as constant, and referred to as a no-load component. The other current component develops motor torque that drives the load, that is, the load on the reel due to the winding tension in the strip, and may be referred to as a load component.

The current going from the rectifier 43 to the field winding 39, in the absence of countervailing provisions, would comprise both components. It is desirable for the field winding 39 of the generator T2 to be energized proportionally to the load component alone, in order that it will respond sensitively to changes of load torque and motor current.

Therefore the constant no-load component of current energizing the field 39 must be eliminated; and this is done by the rectifier 53 and the constant counter potential which it produces, in the field energizing circuit 48—50 as described.

The operation of the above described apparatus is as follows.

As referred to in the premises, one of the primary objects of the invention is to wind the strip 10 on the reel 9 at a preselected constant tension, as the strip is supplied to the reel both at the beginning of the winding operation, and also as the roll on the reel increases in diameter, during winding.

When three phase potential is put on the mains 7, for example by a line switch not shown, connecting the mains to a power source, the motor 6 starts and runs at its constant speed, and drives the input element 2 of the clutch 1 at constant speed.

It will be assumed, for present purposes of description that the mill rolls 11 are running at some constant speed, and that the strip 10 will therefore have constant linear speed; and that the generator T1, driven at a speed proportional to that of the mill rolls will be at constant speed, proportional to strip speed, and will energize the control winding 18 of the amplifier 12 at a constant value.

The amplifier 12 is delivering some output current, by output mains 20—21, to the winding 4 of the clutch 1; and torque is transmitted from the clutch element 2 to the clutch element 3, and this torque drives the reel 9 in the strip winding direction putting tension in the strip; the torque being supplied from the motor 6.

The control winding 18 tends to increase the amplifier output, and if it were acting alone, that is without the opposing control winding 19, the output of the amplifier would be very high, and energization of the clutch winding 4 would be high, the torque transmitted by the clutch 1 to the reel 9 would be at a maximum value and the strip 10 would be put under a maximum tension.

The reel will be driven at considerable speed, since the diameter of the roll forming on the reel at the beginning of the winding operation will be small; and the generator T2 will be driven at a corresponding high speed; and, assuming that its field winding 39 is energized as will be described, the output of the generator T2 in the lines 36 energizes the control winding 19 of the amplifier to a degree proportional to this reel speed.

The control winding 19 by opposing the control winding 18, prevents the torque on the reel 9 and the resulting tension in the strip from attaining said maximum values.

Furthermore, whatever the value of the torque on the reel 9 may be, it is reflected in the value of current taken from the lines 7 by the motor 6; and through the agency of the transformer 40 and rectifier 43, the field winding 39 of the generator T2 will be energized proportionally to the motor current, and therefore proportionally to the load torque on the reel.

This energization of the field winding of generator T2, proportional to the load torque, and concurrently proportional to reel speed, causes the output of the generator T2 to be proportional to the product of torque and speed. The control winding 19, is therefore strongly energized in opposition to the control winding 18 and reduces the amplifier output, and the energization of the clutch winding 4 and the torque on the reel, far below the said maximum values.

For purposes of description, the winding 18 may be considered as energized alone, but only momentarily, because the winding 19 is immediately energized in opposition to it, by the output of the generator T2. Part of the output of generator T2 and energization of the control winding 19 is derived from the motor torque as described, and in consequence the output of the amplifier and energization of the clutch winding 4 thereby, is decreased by the torque from what it would be if the control winding 18 continued to be energized alone.

This decreased energization of the clutch winding and decreased torque is reflected in a decrease of motor current and a decrease of energization of the generator field winding; and a corresponding decrease of the generator output and a decrease of opposition to the control winding 18 by the control winding 19.

It will therefore be apparent that the torque tends to increase energization of the control winding 19 and thereby tends to decrease energization of the clutch winding 4 and this tends to decrease the torque; and at the same time, the decrease of the torque tends to decrease energization of the control winding 19 and thereby tends to increase energization of the clutch winding and increase the torque.

Consequently a balanced or stable regulating condition is reached at which, the output of the generator T2 energizing the control winding 19 causes it to oppose the winding 18 just enough to keep the clutch winding 4 energized by the amplifier at a value that is just enough to cause the motor torque transmitted to the reel to be just enough to produce a certain degree of tension in the strip.

The effect of the opposing winding 19 approaches complete equality with that of the winding 18, but, as described, never quite attains it.

As will be seen, at the start of the winding operation, the reel speed at any instant will be constant, due to the constant speed of the strip, and the said stable regulating condition producing said certain tension in the strip, results from providing the control winding 18, energized at a constant value derived from the constant strip speed which tends to increase the amplifier output; and from opposing its action by the control winding 19 whose energization is derived from the torque applied to the reel, and from the speed of the reel, and which opposition tends to decrease the amplifier output.

The said certain constant value of the strip tension produced at the start, will depend upon the initial diameter of the roll on the reel, and the speed of the strip; and it may be adjusted to a desired tension by the rheostat 38; which adjusts the output of the generator T2 and thereby the energization of the control winding 19, and thereby the torque on the reel, at which the stable condition is arrived at.

As to the adjusting rheostat 51, it may be difficult to provide a resistor 49 and a rectifier 53 having exactly the right values to eliminate the no-load current component in the circuit 48—50 of the field winding 39 as described and the rheostat 51 is provided in this circuit to correct for departures from the exact values of these elements.

As the winding operation goes on, the diameter of the roll on the reel increases, and for any speed of the strip the reel will slow down; and if the torque transmitted to the reel remained the same, the tension in the strip would decrease. To keep the strip tension constant, as of the premises, the transmitted torque must therefore increase.

The inevitable slowing down of the reel decreases the speed of the generator T2, decreasing its output and decreasing the effectiveness of the control winding 19 in opposing the winding 18, and accordingly increasing the effectiveness of the winding 18.

The amplifier responds to the winding 18 and its output increases, increasing energization of the clutch winding 4 and increasing the torque transmitted to the reel. This increase of torque thus corresponds to the decrease of reel speed, which corresponds to the increase of the radius of the roll on the reel so that the tension in the strip remains constant.

The aforesaid regulation to constant strip tension may be described in terms of horsepower, absorbed by the reel; horsepower being defined as torque multiplied by speed of revolution.

Here the torque at any instant is proportional to the tension in the strip. The speed of revolution, at any instant is constant, because of constant speed strip. Hence the horsepower is proportional to the strip tension.

The system regulates to constant strip tension as described and therefore regulates to constant horsepower at the reel.

Unwinding and rewinding

Referring to Fig. 2 of the drawing, is shown at 11 a pair of mill rolls, and strip 10 being processed thereby, moving toward the left and being wound on a reel 9; and the strip coming to mill rolls 11 from a reel 61 on which it has been previously wound.

The diagrammatic figure may be considered as being in two parts on opposite sides of the vertical broken line 62; the left part being substantially a reproduction of Fig. 1, and the parts having the same reference numerals as Fig. 1; with the exception that in the lines 33 from the generator T1, is a reversing switch 63, and in the lines 36 from the generator T2 is a reversing switch 64.

With the reversing switches 63 and 64 thrown to the upper positions shown, the left half of the figure operates as described for Fig. 1 to wind the strip on the reel 9 and to maintain constant tension in the strip 10 coming from the rolls 11; and need not be further described.

The right hand half of the diagram has a second set of parts some of which are substantially like the parts of the left half, and they have been given the same reference characters with the suffix A, to identify them, and in view of the complete description of Fig. 1, a brief description thereof will suffice.

The clutch 1A has an output element 3A connected to the reel 61. The reel 61 is driven by the strip part 10A going to the rolls 11, considered here as at constant speed, and in the unwinding direction. The clutch is energized by the winding 4A. The motor 6A running at constant speed, drives the clutch element 2A in the direction to transmit slipping torque to the output element 3A and reel 61, tending to drive the reel in the winding direction, but the slipping torque yields and permits the reel to go in the unwinding direction and therefore tension is put in the strip at 10A.

The reel 61 drives the generator T2A and the generator energizes the control winding 19A of the amplifier 12A proportionally to reel speed, through output lines 65, and through a reversing switch 66 in these lines.

With the reversing switch 66 in the upper position shown, the right part of the diagram operates to maintain constant tension in the part 10A of the strip 10 between the rolls 11 and the unwinding reel 61, in the same manner as that described for the left part, and therefore will be briefly described.

The generator T2A being driven at the speed of the reel 61, its output energizes the control winding 19A proportionally to speed of the reel.

The value of the torque transmitted to the reel 61 is reflected in the value of the current taken by the motor 6A, and the motor current acting through the agency of the transformer 40A and rectifier 43A, energizes the field winding 39A of generator T2A modifying its output to cause it to energize the amplifier control winding 19A proportionally to torque.

The control winding 18A is energized by the generator T1 proportionally to speed of the strip; and tends to raise the output of amplifier 12A and the energization of the clutch winding 4A to a high value; but the said energization of the control winding 19A jointly proportional to speed and torque in opposition to the constantly energized control winding 18A, limits the output of the amplifier 12A and corresponding energization of the clutch winding 4A, and limits the resulting torque on the reel 61 to a value at which a certain tension is produced in the strip 10A.

Any tendency of the strip tension to change, is counteracted by a change of the output of the generator T2A to the control winding 19A, and a corresponding change of energization of the clutch winding 4A by the amplifier and the said certain strip tension remains constant.

As in the case of the left side of the diagram, the effectiveness of the control winding 19A approaches but never quite attains equality with the effectiveness of the control winding **18A** and the said certain tension in the strip results from their difference.

Adjustment and compensation, as described for the left side of the diagram, provided at the manual rheostats **51** and **38**, is similarly provided at the rheostats **51A** and **38A** in the right side of the diagram; and operates in the same way.

In Fig. 2, the strip **10** moves from right to left, unwinding it from the reel **61** and winding it on the reel **9**. It is contemplated that when the strip has all run through the rolls in that direction, the rolls may be reversed and reset for a successive operation on the strip, and the strip then runs back through the rolls in the other direction, unwinding from the reel **9** and winding on the reel **61**.

To adapt the system of Fig. 2 to this reverse use, all that needs to be done is to throw the reversing switches **64—63—66** to their lower positions with the following effects.

When the rolls **11** reverse, the generator **T1** is driven in the reverse direction and would reverse the polarity of the control windings **18** and **18A**, but this is prevented by throwing the reversing switch **63** to its lower positions.

Also when the rolls reverse, the strip **10** reverses in direction moving toward the right and the reels **9** and **61** reverse their directions.

The reels then drive the generators **T2** and **T2A** in the reverse direction and this would reverse the polarity of the control windings **19** and **19A** but is prevented from doing so by throwing the reversing switches **64** and **66**, to their lower positions.

The polarities of the control windings thus being unchanged, the system operates as described, but with the reel **9** being the unwinding reel and the reel **61** the winding reel.

In a broad aspect of the invention, as described above, the winding reel of Fig. 1 or Fig. 2, or the unwinding reel of Fig. 2, may be considered when it has a roll of strip thereon, with a portion of the strip extending therefrom tangentially; and maintained in the tangential portion of the strip by applying torque to the reel that varies inversely as the speed of the reel, and directly as the diameter of the roll on the reel as it changes during winding or unwinding.

And if the slipping clutch be included in this broad aspect of the invention then, to keep the strip tension constant, the applied torque varies with energization of the clutch winding, and the value of clutch winding energization varies inversely as the speed of the reel, and varies inversely with the applied torque itself as it tends to vary, or varies directly with changes of the roll diameter as it winds on or unwinds from the reel.

For purposes of simplifying the foregoing description the motor **6** of Fig. 1 and the motors **6** and **6A** of Fig. 2, are described as constant speed synchronous motors.

However, it is within the scope of the invention to utilize induction motors for example three phase induction motors, and in some cases induction motors will be preferred; and a brief description related thereto follows.

As is well known, the speed of an induction motor is not constant, but slows down as an increase of output load is put on it. As it slows down its output torque rises and the current which it takes from the line rises, and vice versa. With an induction motor chosen to be of horsepower suitable for the control hereof, and having a range of torque output suitable to meet the demands of the control, the current taken by the motor will be proportional to the torque in said range.

In the foregoing description, using a synchronous motor, an increase of torque demand on the motor is described as reflected in an increase of current taken by the motor, and the increase of current is utilized to cause an increase of energization of the field winding **39** of the generator **T2**.

Thus, part of the description therefore applies to an induction motor.

The principal difference in utilizing an induction motor that has varying speed with varying torque, in place of a synchronous motor that has constant speed with varying torque, is that, for example in Fig. 1, when the reel **9** demands more torque from the motor and it slows down, the input element **2** of the clutch **1** slows down. But as stated hereinbefore the clutch has the characteristic that for a given energization by its winding **4**, its transmitted torque remains the same for different speeds of its input element.

Thus slowing down of the motor because it is an induction motor has no effect on the operation of the control.

For purposes of simplifying the foregoing description, the strip speed has been referred to as constant, determined in value by constant speed mill rolls.

It is obvious that this constant strip speed will be of different value for different speeds of the mill rolls; and that the control will operate to produce constant strip tension at all constant speeds of the strip.

Furthermore, it is believed to be apparent that the control will operate to maintain constant strip tension if the speed of strip is not constant but varies continuously, as for example in cases in which the strip speed is dictated by some strip processing apparatus other than mill rolls; or by mill rolls that for some reason are driven at variable speed.

The invention therefore is not limited to constant strip speed, but is comprehensive of variable strip speed and of all changes in and modifications of the specific embodiments illustrated and described and which may occur to those skilled in the art and which come within the scope of the appended claims.

We claim:

1. A control for maintaining constant tension in a strip that is being wound on a reel and that comes to the reel at constant linear speed, the control comprising a motor, and a slipping clutch between the motor and the reel; the clutch having an energizing winding and constructed to transmit torque from the motor to the reel commensurable with energization of the winding; a generator driven at speed proportional to reel speed and having an output commensurable with its speed; the generator having a field winding; means energizing the field winding commensurably with the torque transmitted to the reel to thereby vary the generator output commensurably with variations of transmitted torque; and means energizing the clutch winding commensurably with changes of generator output effected by changes of reel speed and transmitted torque.

2. A control for maintaining constant tension in a strip as it is being wound on a reel and that comes to the reel at constant speed, the control comprising; a reel drive comprising a motor, and a slipping clutch between the motor and the reel; the clutch having an energizing winding and constructed to transmit torque from the motor to the reel commensurable with energization of the winding; a generator driven at speed proportional to reel speed and having an output commensurable with its speed; the generator having a field winding; means energizing the field winding commensurably with the torque transmitted to the reel to thereby vary the generator output commensurably with variations of transmitted torque; a magnetic amplifier energized from a current source and delivering amplifier output to the clutch winding; the amplifier having a control winding, variable energization of which varies the output to the clutch winding; the control winding connected to be energized by the generator output commensurably with changes of generator output effected by changes of reel speed and transmitted torque.

3. A control for maintaining constant tension in a strip

that is being wound on a reel and that comes to the reel at constant linear speed, the control comprising a drive for the reel including a motor, and a slipping clutch between the motor and the reel; the clutch having an energizing winding and constructed to transmit torque from the motor to the reel commensurable with energization of the winding; a generator driven at speed proportional to reel speed and having a D.C. output commensurable with its speed; the generator having a field winding; means energizing the field winding commensurably with the torque transmitted to the reel to thereby vary the generator output commensurably with variations of transmitted torque; a magnetic amplifier energized from a current source and delivering amplifier output to the clutch winding; the amplifier having a first and a second D.C. control winding in opposition, the resultant energization of which varies the amplifier output; means energizing the first control winding at constant value commensurably with the strip speed; means connecting the second control winding to be energized by the generator output commensurably with changes of generator output effected by changes of reel speed and transmitted torque.

4. The apparatus described in claim 3 and in which the means for energizing the first control winding at speed commensurable with the strip speed is another D.C. generator having a constant field and driven at speed proportional to the strip speed.

5. The apparatus described in claim 1 and in which the motor is an electric motor supplied with current from source mains, and the means energizing the generator field winding commensurable with the torque transmitted to the reel comprises means deriving current from the motor supply mains proportional to the torque and energizing the generator field therewith.

6. The apparatus described in claim 3 and in which the motor is an electric motor supplied with current from source mains, and the means energizing the generator field winding commensurable with the torque transmitted to the reel comprises means deriving current from the motor supply mains proportional to the torque and energizing the generator field therewith.

7. The apparatus described in claim 2 and in which an adjusting rheostat is provided to adjust the energization of the control winding.

8. The apparatus described in claim 3 and in which an adjusting rheostat is provided to adjust the energization of the second control winding.

9. The apparatus described in claim 2 and in which an adjusting rheostat is provided to adjust the energization of the field winding.

10. The apparatus described in claim 3 and in which an adjusting rheostat is provided to adjust the energization of the field winding.

11. A control for maintaining constant the tension in a strip that is being unwound from a reel and that leaves the reel at constant linear speed and drives the reel in the unwinding direction, the control comprising a motor and a slipping clutch between the motor and the reel applying torque to the reel in the winding direction; the clutch having an energizing winding and constructed to transmit torque from the motor to the reel commensurable with energization of the winding; a generator driven at speed proportional to the reel speed and having an output commensurable with its speed; the generator having a field winding; means energizing the field winding commensurably with the torque transmitted to the reel to thereby vary the generator output commensurably with variations of transmitted torque; and means energizing the clutch winding commensurably with changes of generator output effected by changes of reel speed and transmitted torque.

12. A control for maintaining constant the tension in a strip that is being unwound from a reel and that leaves the reel at constant linear speed and drives the reel in the unwinding direction, the control comprising a motor and a slipping clutch between the motor and the reel applying torque to the reel in the winding direction; the clutch having an energizing winding and constructed to transmit torque from the motor to the reel commensurable with energization of the winding; a generator driven at speed proportional to the reel speed and having an output commensurable with its speed; the generator having a field winding; means energizing the field winding commensurably with the torque transmitted to the reel to thereby vary the generator output commensurably with variations of transmitted torque; a magnetic amplifier energized from a current source and delivering amplifier output to the clutch winding; the amplifier having a control winding, variable energization of which varies the output to the clutch winding; the control winding connected to be energized by the generator output commensurably with chainges of generator output effected by changes of reel speed and transmitted torque.

13. A control for maintaining constant tension in a strip that is being unwound from a reel at constant linear speed and rotates the reel in the unwinding direction, the control comprising a motor and a slipping clutch between the motor and the reel applying torque to the reel in the winding direction; the clutch having an energizing winding and constructed to transmit torque from the motor to the reel commensurable with energization of the winding; a generator driven at speed proportional to the reel speed and having a D.C. output commensurable with its speed; the generator having a field winding; means energizing the field winding commensurably with the torque transmitted to the reel to thereby vary the generator output commensurably with variations of transmitted torque; a magnetic amplifier energized from a current source and delivering amplifier output to the clutch winding; the amplifier having a first and a second D.C. control winding in opposition, the resultant energization of which varies the amplifier output; means energizing the first control winding at a value commensurably with the strip speed; means connecting the second control winding to be energized by the generator output commensurably with changes of generator output effected by changes of reel speed and transmitted torque.

14. The apparatus described in claim 13 and in which the means for energizing the first control winding at speed commensurable with the strip speed is another D.C. generator having a constant field and driven at speed proportional to the strip speed.

15. The apparatus described in claim 11 and in which the motor is an electric motor supplied with current from source mains, and the means energizing the generator field winding commensurable with the torque transmitted to the reel comprises means deriving current from the motor supply mains proportional to the torque and energizing the generator field therewith.

16. The apparatus described in claim 12 and in which the motor is an electric motor supplied with current from source mains, and the means energizing the generator field winding commensurable with the torque transmitted to the reel comprises means deriving current from the motor supply mains proportional to the torque and energizing the generator field therewith.

17. The apparatus described in claim 13 and in which the motor is an electric motor supplied with current from source mains, and the means energizing the generator field winding commensurable with the torque transmitted to the reel comprises means deriving current from the motor supply mains proportional to the torque and energizing the generator field therewith.

18. The apparatus described in claim 12 and in which an adjusting rheostat is provided to adjust the energization of the control winding.

19. The apparatus described in claim 13 and in which an adjusting rheostat is provided to adjust the energization of the second control winding.

20. The apparatus described in claim 11 and in which an adjusting rheostat is provided to adjust the energization of the field winding.

21. The apparatus described in claim 12 and in which an adjusting rheostat is provided to adjust the energization of the field winding.

22. The apparatus described in claim 13 and in which an adjusting rheostat is provided to adjust the energization of the field winding.

23. A control for maintaining constant tension in a strip as it is being unwound from a first reel and drives the first reel, and constant tension in the strip as it is being wound on a second reel that is power driven and when the strip between the reels is maintained at constant linear speed, the control comprising two slipping clutches through which torque is transmitted to the respective reels both in the winding direction, from two corresponding electric motors; the clutches having respective energizing windings and the values of their transmitted torques being commensurable with the energization of their windings; the motors taking current from supply mains proportional to their transmitted torques; two electric generators having respective output circuits; and having respective field windings; means energizing the respective field windings with currents proportional to the currents taken by the respective motors; and means driving the generators at speeds proportional to the respective reel speeds; whereby the generator output currents are directly proportional, respectively, to the speeds of the reels, and to the torques applied thereto; and means actuated by the output currents of the generators, and energizing the respective clutch windings inversely proportional to the output currents of the generators.

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