Nov. 30, 1937. L. A. UMANSKY 2,100,653

CONTROL SYSTEM

Filed Sept. 27, 1935

Fig. 1.

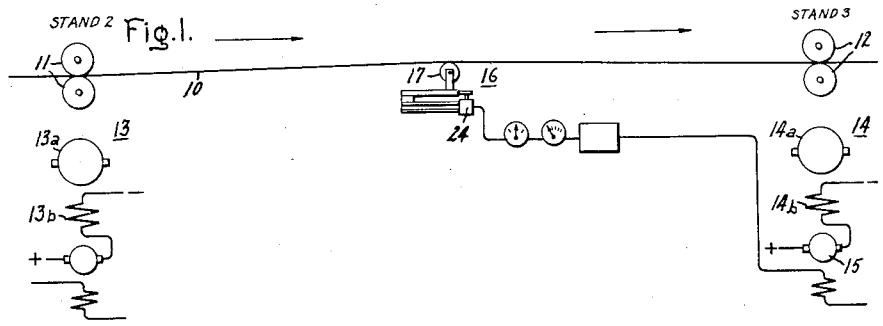


Fig. 2.

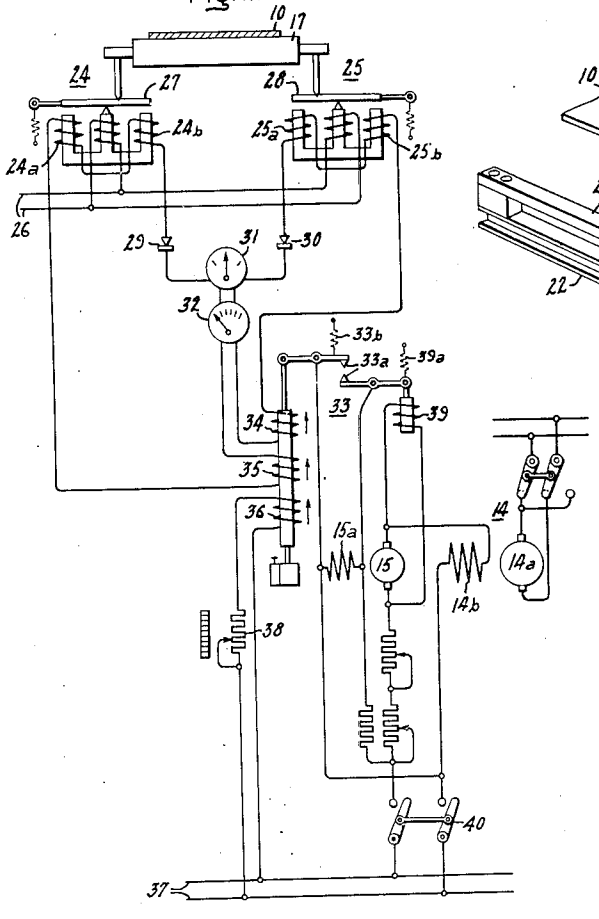


Fig. 3.

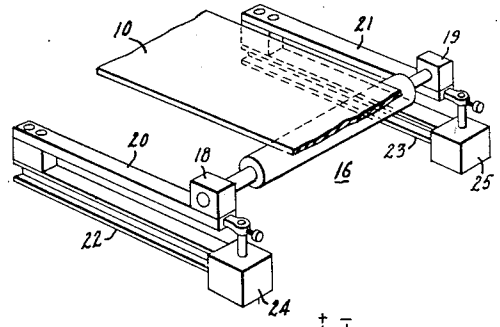
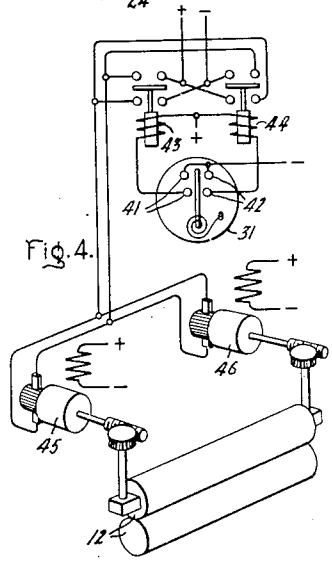


Fig. 4.



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Patented Nov. 30, 1937

2,100,653

UNITED STATES PATENT OFFICE

2,100,653

CONTROL SYSTEM

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Application September 27, 1935, Serial No. 42,439

14 Claims. (Cl. 80—35)

This invention relates to control systems, more particularly to control systems for apparatus having an element operating on a strip of material, and it has for an object the provision of a simple, reliable and improved control system of this character.

More specifically, the invention relates to systems for controlling the tension of the strip and a more specific object of the invention is the provision of reliable and improved means for directly measuring the strip tension and controlling the apparatus so as to maintain the tension substantially constant at a predetermined value.

Another object of this invention is the provision of means for separately measuring the strip tension at both edges of the strip and also for indicating the difference between the tensions at both edges of the strip.

An additional object of the invention is the provision of means responsive to a difference in the tension on opposite sides of the strip for controlling the screw down mechanism in such a manner as to equalize the tension at both edges of the strip.

In carrying the invention into effect in one form thereof, an electric motor and means driven thereby produce a tension in the strip, and a variable air gap device is provided for responding to slight variations from a predetermined value of the strip tension and controlling the motor to maintain the strip tension substantially constant. The motor driven means acting on the strip may be a pair of rolls or a reel.

In illustrating the invention in one form thereof, it is shown as embodied in a control system for a tandem cold strip rolling mill. The invention, however, is equally applicable to other types of apparatus, such for example as a reversing type strip mill.

For a better and more complete understanding of the invention, reference should now be had to the following specification and to the accompanying drawing in which Fig. 1 is a simple diagrammatical illustration of an embodiment of the invention; Fig. 2 is a simple schematic diagram of the electrical apparatus and connections; Fig. 3 is a detail of the tension responsive device; and Fig. 4 is a detail illustrating automatic control of the screw down motors.

Referring now to the drawing, a strip of material 10 is passed in the direction of the arrows through pairs of rolls 11 and 12. The pairs of rolls 11 and 12 may be assumed to be the rolls of the second and third stands respectively of a continuous cold strip rolling mill. The rolls 11 are driven by suitable driving means illustrated as a direct curent electric motor 13 having an armature member 13_a supplied from a suitable source (not shown) and a field winding 13_b supplied from a suitable source represented by plus and minus signs. A small counter-electromotive force generator is included in circuit with the field winding. Similarly, the pair of rolls 12 is driven by a direct current electric motor 14, the armature member 14_a of which is supplied from a suitable source (not shown) of direct voltage and having a field winding 14_b supplied from a suitable source represented by plus and minus signs and having the armature of a small counter-electromotive force generator 15 included in circuit therewith.

The stands 2 and 3 are separated from each other by a substantial distance. In one actual installation, these stands are on 16' centers. At a point between these stands, preferably at the midpoint, a "tension control stand" 16 is located. It comprises a roller 17 journaled in suitable roller or ball bearings 18, 19. Each bearing is resiliently supported by a standard or pedestal. As shown, the bearings 18 and 19 are respectively mounted on the free ends of plates 20, 21, which are approximately 1'' thick and 20'' long. At the opposite ends, these plates are fastened to suitable base members illustrated as I-beams 22, 23. Thus, the plates act as rather stiff cantilever springs. The springs 20, 21 may of course be designed for any desired modulus. In an actual installation the springs are so designed that a thousand pound load on the bearings will produce a deflection of approximately ⅛''. Lighter loads will produce proportionally smaller deflections, as is well understood.

The roller 17 is substantially the same length as the mill rolls and it is so centered as to deflect the strip upwardly a short distance, for example, 2'' to 3'' from the horizontal pass line between the rolls 11 and 12. Thus, the strip tension produces a vertical component, the value of which depends on the ratio of elevation of the top of the roller 17 above the horizontal pass line to the distance between the stands. If it is assumed that the total strip tension is seventy-thousand pounds, the distance between the centers of stands 16 feet and the deflection of the strip above the path line is 2 inches, the vertical component, i. e. the thrust on the roller 17 will be fourteen hundred and sixty pounds and the load on each bearing will be seven hundred and thirty pounds. Thus, a very substantial tension places but a relatively light load on the roller.

The electrical system for regulating the tension in the strip is shown in Fig. 2, in which the mechanical parts such as the bearings and supports of the roller 17 are omitted for the sake of clearness.

The deflections of the ends of the rolls 17 are transmitted to electrical devices 24, 25. These devices are illustrated as variable air gap inductive devices, constructed preferably in the form of variable air gap three legged transformers. The middle legs of these transformers 24 and 25 are respectively provided with primary windings which are energized from a suitable source of alternating voltage represented by the supply lines 26. The secondary winding of the transformer 24 comprises two coils 24_a and 24_b wound on opposite outside legs of the core and connected in series relationship and in opposition to each other. Similarly, the secondary winding of the transformer 25 comprises two coils 25_a and 25_b similarly mounted and connected. Armature members 27 and 28 respectively complete the magnetic paths of these transformers. These armature members are respectively pivoted on the middle legs and are balanced in position by suitable spring means as illustrated. When the armature members 27 and 28 are in the horizontal balanced positions shown and the air gaps between each armature member and the two outside legs of its core member are equal, the voltages induced in the windings on the outside legs are equal and opposite and consequently no current flows in the secondary windings. When one of these armatures is tilted in response to a deflection of the roller by the tension of the strip, the voltage balance of the windings on the outside legs of each transformer is upset and a current flows in the secondary circuit.

The output current of the secondary windings of both transformers 24 and 25 is converted into direct current by means of suitable rectifying means indicated as copper oxide rectifiers 29 and 30. Rectification of the alternating current output of transformers 24 and 25 facilitates the application of the output of these transformers for control purposes.

These rectified currents which are measures of the strip tension at both edges, are carried through two indicating means 31 and 32. As indicated, the meter 31 is a differential meter and has a zero center scale. Thus, if the tension is equal at both edges of the strip, the meter 31 reads zero. If the tension at the edges of the strip is unequal, the indicating element of the meter will be deflected to the right or to the left indicating at which edge, the tension is the greater. The operator, guided by this indication, adjusts the setting of the left or right screw, or both, to restore the balance.

The rectified currents are then carried through the ammeter 32, which indicates the sum or the average of both current values. Thus, this instrument serves as a tensiometer indicating the total strip tension. In order to maintain the total strip tension substantially constant at a desired value, suitable regulating means shown as a vibratory contact type regulating device 33 actuated by the rectified currents of the transformers 24 and 25 is provided. The main magnet of this regulating device is energized by three coils, 34, 35, and 36. The coils 34 and 35 carry the output current of the transformers 25 and 24 respectively and are connected to act cumulatively with each other so that the combined action of these two coils represents the average strip tension between stands 2 and 3 of the mill. The coil 36 is energized from a suitable constant potential direct current source represented by the two supply lines 37. A variable resistance 38 is included in the connections between the coil and the source. As indicated by the arrows, the coil 36 is so energized that it acts cumulatively with the coils 34 and 35. Consequently, the greater the current which flows in the coil 36, the smaller will be the current flowing in the coils 34 and 35 necessary to maintain the regulator in balance. Thus, the variable resistance 38 serves to change the setting of the regulator so as to cause it to maintain a greater or a smaller value of strip tension. Preferably the rheostat 38 is provided with a suitably calibrated scale for indicating the magnitude of the tension which the regulator is set to hold.

The contacts 33_a of the regulator act on the field winding 15_a of the smaller counter E. M. F. exciter 15 the armature of which is included in the connections between the field windings 14_b of the mill motor and its source of excitation 37. As shown, the regulator 33 is provided with an anti-hunting coil 39 which is connected across the armature terminals of the exciter 15 so as to be responsive to the armature voltage.

With the above understanding of the apparatus and its organization in the completed system, the operation of the system itself will readily be understood from the following detailed description:

The movable contact member of the variable resistance 38 is set by the aid of the scale to a desired value of tension. The switch 40 is moved to its closed position to connect the field winding 14_b of the mill motor to the source 37. If the strip tension exceeds this predetermined value, the roller 17 is deflected and tilts the armatures 27 and 28 against their spring tensions. This unbalances the voltages in the secondary windings of each transformer and causes current to flow in the coils 34 and 35 of the regulator. Since the coils 34 and 35 act cumulatively with the coil 36, the regulator is caused to close its contacts 33_a against the tension of the spring 33_b. In closing, the contact 33_a short circuits the field winding 15_a of the C. E. M. F. generator 15, causing the voltage of the latter to decrease. Since the voltage of the generator 15 is in opposition to the voltage of the source 37, the excitation of the field winding 14_b is increased, and as a result the speed of the mill motor 14 is decreased. As the speed of the mill motor 14 decreases, the tension of the strip likewise decreases.

At the same time that the excitation of the generator 15 decreases, the energization of the anti-hunting coil 39 likewise decreases, with the result that the spring 39_a overpowers the pull of the magnet 39 and moves the lower member of the contact 33_a out of engagement with the upper member thereby interrupting the short circuit about the field winding 15_a, thereby to increase the excitation of the generator 15. Since the voltage of the generator 15 opposes the voltage of the source 37, the field strength of the motor 14 is weakened and the speed of the motor is thereby increased. However, as soon as the voltage of the exciter 15 increases, the magnet 39 overpowers the spring 39_a and the lower contact member 33_a is again actuated into engagement with the upper contact member to reestablish the short circuit about the field winding 15_a. This cycle is rapidly repeated, the lower contact member 33_a vibrating rapidly to hold a mean value of

excitation of exciter 15, depending upon the position of the upper contact member 33a. The vibratory action of the anti-hunting coil which is responsive to the voltage of the exciter 15, is so rapid that owing to the time lag of the field winding of the motor 14, the current in the motor field winding is held substantially constant so that no periodic effect on the tension is produced by this anti-hunting means.

If the strip tension falls below the value predetermined by the setting of the variable resistance 38, the currents in the coils 34 and 35 decrease so that the tension of the spring 33b overpowers the pull of the magnet and operates the contact 33a. This, of course, increases the excitation of the exciter 15 and decreases the excitation of the mill motor 14, causing the speed of the latter to be increased and thereby to increase the tension of the strip.

If automatic equalization of the strip tension at the edges is desired, the differential meter 31 is equipped with a pair of contacts 41 and a second pair of contacts 42, which are connected in the energizing circuit of the forward and reverse contactors 43 and 44 for the screw down motors 45 and 46. These screw down motors are connected in parallel with each other to a supply source when one or the other of the contactors 43 or 44 is closed, and they are so connected that when the motor at one end is opening the rolls, the motor at the other end is closing the rolls. Thus, if the tension of the left-hand edge of the strip is greater than the tension at the right-hand edge, the movable contact member of the differential meter 31 is actuated into engagement with the stationary contact 41 to complete an energizing circuit for the forward contactor 43 which closes its contacts to connect the motors 45 and 46 to a suitable supply source represented by the plus and minus signs. The motors 45 and 46 are energized for rotation in a direction such that the motor 45 opens the rolls and the motor 46 at the opposite end closes the rolls, thereby decreasing the strip tension at the left hand edge and increasing it on the right hand edge. When the tension is equalized the movable contact member of the meter 31 moves to its zero position, deenergizing the contactor 43 which thereupon opens its contacts and disconnects the motors 45 and 46 from the supply source. If the tension at the right hand edge of the strip should exceed the tension on the left hand edge, the movable contact member will be actuated into engagement with the stationary contact members 42 to complete an energizing circuit for the reverse contactor 44. The reverse contactor 44 will then close in response to energization and connect the screw down motors 45 and 46 to the supply source for rotation in a direction such that the motor 45 will close the rolls and the motor 46 at the opposite end will open the rolls. When the tensions at the two edges of the strip become equal the meter 31 again deenergizes and stops the motors.

Although in accordance with the provisions of the patent statutes, this invention is described as embodied in concrete form, it will be understood that the apparatus shown and described is merely illustrative and the invention is not limited thereto since alterations and modifications will readily suggest themselves to persons skilled in the art, without departing from the true spirit of this invention or from the scope of annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In combination with means for performing an operation on a length of material, a dynamoelectric machine and means operatively connected therewith for producing a tension in said material, an electrical device having a pair of relatively movable elements separated by an air gap, means responsive to relative movement of said elements for controlling said dynamoelectric machine to vary the tension in said material, and means responsive to variations in the tension of said material for effecting relative movement of said elements thereby to control said dynamoelectric machine to maintain said tension substantially constant.

2. In combination with means for performing an operation on a length of material, a dynamoelectric machine and means operatively connected therewith for producing a tension in said material, a device at each edge of said material for measuring the tension, a differential device controlled by both said tension measuring devices for indicating the difference in tension at said edges, and means responsive to variations in the average of said tensions for controlling said dynamoelectric machine to maintain said average tension substantially constant.

3. A control system for apparatus having an element operating on a length of material comprising in combination a dynamoelectric machine and means operatively connected therewith for producing a tension in said material, an electrical inductive device having a pair of relatively movable elements separated by an air gap, means responsive to relative movement of said elements for controlling said dynamoelectric machine to vary the tension in said material, and means responsive to variations in the tension of said material for effecting relative movement of said elements to vary said air gap and thereby to control said dynamoelectric machine to maintain the tension in said strip substantially constant.

4. A control system for rolling mill drives and the like having an element operating on a strip of material comprising a dynamoelectric machine, and means operatively connected therewith for producing a tension in said strip, variable air gap transformer means for controlling said dynamoelectric machine, and means responsive to variations in the tension of said strip for varying the air gap of said transformer to control said dynamoelectric machine to maintain the tension of said strip substantially constant.

5. Tension controlling means for strip rolling mills and the like comprising a dynamoelectric machine and means operatively connected therewith for producing a tension in the strip, variable air gap transformer means arranged to have its air gap varied in response to variations of tension in said strip and regulating means controlled by said transformer means for controlling said dynamoelectric machine to maintain the tension in said strip substantially constant.

6. Tension controlling means for apparatus having an element operating on a strip of material comprising a dynamoelectric machine and means operatively connected therewith for producing a tension in the strip, variable air gap transformer means arranged to have its air gap varied in response to variations in the tension of the strip, and vibrating contact means controlled by said transformer for controlling the excitation of said dynamoelectric machine to maintain the tension in said strip substantially constant.

7. Tension controlling means for apparatus

having an element operating on a strip of material comprising in combination a dynamoelectric machine and means operatively connected therewith for producing tension in the strip, a variable air gap transformer, means responsive to variations in the tension in said strip for varying the air gap of said transformer comprising an idler roller and a cantilever spring mounting for said roller, and means controlled by said transformer means for controlling the excitation of said dynamoelectric machine to maintain the tension of said strip substantially constant.

8. Tension controlling means for apparatus having an element operating on a strip of material comprising a dynamoelectric machine and means operatively connected therewith for producing a tension in the strip, a pair of variable air gap transformers arranged on opposite sides of said strip so that the air gap of each is varied in response to variations in the tension of a corresponding edge of said strip, means for controlling the excitation of said dynamoelectric machine to maintain the tension of the strip substantially constant comprising a regulating device having an operating winding and connections from said winding to the secondary windings of said transformers, a differential indicating device included in said connections for indicating the difference of the tension on opposite sides of said strip, a device included in said connection for indicating the average tension of said strip, and means for adjusting the setting of said regulator to maintain a selected value of tension.

9. A control system for a strip rolling mill having a screw down for varying the opening between the rolls, electric motor means for actuating said screw down, a pair of variable air gap transformers arranged to have their air gaps varied in response to variations in strip tension on opposite sides of said strip, and an electrical differential device connected to said transformers for controlling said motor means to equalize the tension on opposite sides of the strip.

10. A control system for a strip rolling mill having a screw down and a pair of motors, one at each end of said screw down for varying the opening between the rolls of said mill, a pair of variable air gap transformers arranged one on each side of the strip to have their air gaps varied in accordance with the tension of the strip on opposite sides thereof, and a differential device connected to the secondary windings of said transformer for energizing one of said motors to increase the opening between said rolls at one end and for energizing the other of said motors to decrease the roll opening at the opposite end thereby to equalize the tension on opposite sides of said strip.

11. A control system for apparatus for performing an operation on a length of material comprising in combination a dynamoelectric machine and means operatively connected therewith for producing a tension in the material, a pair of inductive devices arranged at opposite edges of said length of material and each having an air gap and means for varying said air gap in response to variations in the tension of said material and means responsive to variations in said air gaps for controlling said dynamoelectric machine to maintain said tension substantially constant.

12. A control system for performing an operation on a length of material, comprising in combination a dynamoelectric machine and means operatively connected therewith for producing a tension in said length of material, a pair of electrical inductive devices arranged at opposite edges of said length of material and each having a primary and secondary winding separated by an air gap and a movable armature for varying said air gap, means for moving said armatures in accordance with variations in the tension of said material at each of said edges to produce corresponding variations in the voltages of said secondary windings comprising a roll over which the material passes, means mounting said roll for movement in response to variations in said tension, and a mechanical connection between each end of said roll and a corresponding one of said armatures, and means responsive to said variations in voltage for controlling said dynamoelectric machine to maintain the average tension of said strip substantially constant.

13. A device for measuring tension in a length of material comprising a pair of electrical inductive devices arranged at opposite edges of the material and each having a primary winding and a secondary winding separated by an air gap and means for varying said air gap in response to variations in tension at the corresponding edge of said material thereby to produce variations in the voltages of said secondary windings, and an electrical measuring instrument electrically connected to said secondary windings.

14. Tension controlling means for apparatus having an element operating on a length of material comprising a dynamoelectric machine and means operatively connected therewith for producing a tension in said material and means responsive to variations in said tension for maintaining said tension substantially constant comprising an electrical device having a core member, a primary winding mounted on said core, a secondary winding mounted on said core and divided into two portions wound in opposition to each other, and an armature member separated from said core member by an air gap and movable in response to variations in said tension for varying said air gap thereby to unbalance the voltages in said secondary winding, and means responsive to said voltages for controlling said dynamoelectric machine.

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