

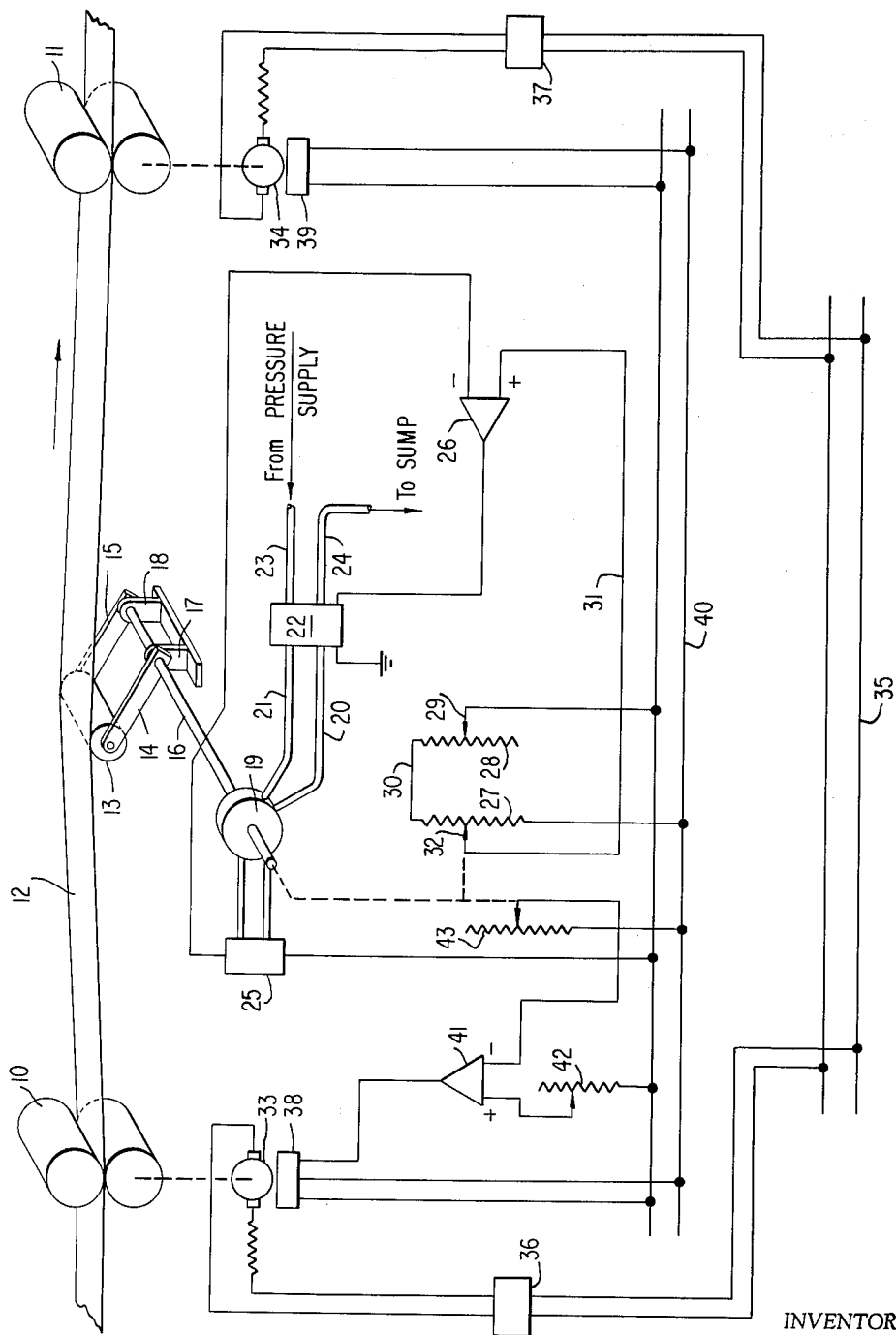
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J. H. TORRANCE

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TENSION CONTROL SYSTEM

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TENSION CONTROL SYSTEM

James H. Torrance, Uncasville, Conn., assignor to General Dynamics Corporation, New York, N.Y., a corporation of Delaware

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9 Claims. (Cl. 72-205)

This invention is directed to the subject matter of my former application Serial No. 266,632, filed March 20, 1963, now abandoned, is a continuation-in-part thereof and relates generally to tension controlling apparatus and is particularly directed to improvements in automatic tension control systems for maintaining a constant predetermined tension on the strip material passing between the spaced rolls of a tandem or continuous rolling mill.

In the rolling of strip metal in a tandem rolling mill, the usual practice is to maintain tension in the strip undergoing reduction at a fixed force level. Tension on the strip is an extremely important factor in the reduction and quality of the strip; thus it must be accurately controlled. The general means of controlling the tension on strip between adjacent roll stands is by way of a looper between such stands. This looper is a mechanical device which forces an idler roller against the strip to apply a given amount of tension. There are two types of loopers in common use; one mounts an idler roll on arms connected to a pivot shaft which is rotated to bring the roll against the strip, and the second type acts in a vertical mode wherein the idler roll is moved along a track. Although the current invention may be used with either type looper, it is particularly valuable with the rotary type, which is by far the most commonly installed.

In prior control systems associated with such loopers, the operating approach for tension control has been to maintain a fixed angle or constant torque on the actuating mechanism for the looper and to control the tension on the strip through the control of the relative speed of adjacent roll stand motors, using small variations in looper position to signal the required stand motor speed changes.

It is the primary object of the present invention to provide an improved automatic control system including tension maintaining apparatus which will maintain a substantially constant tension on the strip between roll stands over the entire operating range of the apparatus.

A specific object of the invention is to provide an improved automatic tension mechanism positioned between spaced roll stands in a strip rolling mill which may be pre-set to a given point in an operating range, which will automatically maintain that tension within the operating range, and which has ancillary means interconnected between the apparatus and the drive motor for one of the roll stands whereby to adjust the speed of the drive motor sufficiently to keep the tension apparatus within the operating range.

A further object of this invention is to provide an electro-hydraulic actuated tension maintaining apparatus between the spaced rolls of a tandem rolling mill wherein through the medium of a balanced electro-hydraulic control system associated with an hydraulic actuator, a pre-set tension introduced into the control system as an electrical signal will be transmitted to the strip by means of the actuator and will be maintained on the strip over

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a fixed operating range, and wherein means associated with the actuator is operative to vary the speed of one of the drive motors at a roll stand to keep the tension of the strip sufficiently adjusted that the tension maintaining apparatus is kept within its operating range.

A still further object of this invention is to provide an electro-hydraulic tension maintaining system to act through a tension roll on the strip material extending between spaced rolls of a tandem rolling mill in which tension deviations are instantaneously transmitted through control means to an actuator for the roll, whereby to adjust the position of a tension roll to maintain a substantially fixed tension level.

With the foregoing and other objects in view, the invention resides in the following specification and appended claims, certain embodiments thereof being illustrated in the accompanying drawing in which the figure schematically represents a tandem rolling mill and the associated tensioning mechanism of the invention with the schematically illustrated electro-hydraulic control circuit connected thereto.

Referring more particularly to the drawing, a tandem rolling mill comprised of spaced roll stands 10 and 11 (each shown as a pair of rolls) is illustrated as advancing and reducing a strip of sheet steel, for example, to the right as illustrated by the arrow. The strip 12 would normally move in a straight line between the roll stands 10 and 11, but is depicted as being moved upwardly by an intermediate tension roll 13 carried by suitable arms 14 and 15. The arms 14 and 15 are interconnected with a shaft 16 which is rotatably journaled in mounting stands 17 and 18. The shaft 16 is interconnected with an hydraulic actuator 19 of the rotary type. This actuator may be of any suitable type in which a pressure differential generated in the actuator will be changed into a mechanical rotary output force.

The actuator 19 is interconnected by fluid lines 20 and 21 to a control valve 22. This control valve may be any suitable type of normally balanced valve which has an electric actuator to move a central fluid directing member so as to control the flow of pressure fluid between a pressure line 23 and the actuator control lines 20 and 21. For example, the pressure line 23 is connected to a suitable source of liquid pressure (not shown) while the line 24 is a return line to the sump of the pressure system (not shown).

Also connected with the hydraulic actuator 19 is an electric pressure transducer unit 25 which is capable of sensing deviations in pressure differential, and thus the torque of the actuator, across the hydraulic actuator 19 and includes means for converting said pressure differential into electric signals.

Associated with the hydraulic portion of the system is an electric circuit including an amplifier 26, a balancing, non-linear, resistor 27 and an input control resistor 28. By moving the control tap 29 on the resistor 28, an input signal representative of the desired tension force to be placed on the strip 12 is introduced via the lead 30, resistor 27 and lead 31 into the amplifier 26. The electrically operated control valve 22 will be unbalanced by the signal coming from the amplifier 26 to the extent that the actuator 19 will be rotated to move the shaft 16 clockwise and hence move the idler roller 13 upwardly into engagement with the strip 12. As the roll 13 is moved upward-

ly, an extension of the shaft 16 extending through the actuator 19 will move the contact arm 32 on resistor 27 through suitable linkage, illustrated by dotted lines, until a balanced electrical condition is reached in the system, at which time the actuator will cease rotation and the roll 13 will have reached a null position indicative of the desired tension force on the strip 12. The hydraulic actuator 19 is such that in the null condition just mentioned, a considerable pressure differential will exist as a result of the web acting on the roll 13. Consequently, any deviations in strip tension created by various factors will be apparent as changes in the pressure differential occur between sections of the actuator. Upon the occurrence of such deviations, the output of the pressure transducer 25 will change, unbalancing amplifier 26 and causing the control valve 22 to adjust the pressure flow to and from the actuator 19 to rotate the same sufficiently to establish a new null position for the roll 13 which will be that position in which the predetermined set tension is re-established.

The non-linear resistor 27 compensates for the nonlinearities inherent in the looper system and provides a signal directly proportional to the actuator torque required for the desired tension. Referring to the drawing, an examination of the geometry will show that the strip tension for a given actuator torque varies with the position of the looper. Therefore, in order to maintain a constant tension in the strip, means must be provided to vary the actuator torque as a function of the looper angle. The variation in actuator torque is accomplished by the use of the non-linear resistor 27, which modifies the input signal as a function of looper angle. This modified input signal produces the necessary variation in the actuator torque to maintain constant tension in the strip independent of the looper position.

It is quite obvious that the physical arrangement of the roll 19 and its mounting means can be effective only over a fixed arcuate range. This range would be effective between a position of initial contact of the roll 13 with the strip 12 and a position wherein the support arms 14 and 15 were at right angles to the strip. Therefore, with this rather limited arcuate path constituting a fixed operating range for the automatic tension maintaining apparatus, it is desirable to combine with the apparatus means whereby the strip tension may be otherwise accordingly varied so that the tension maintaining apparatus is always operating within its fixed range. Associated with each of the drive rolls 10 and 11 are drive motors 33 and 34 illustrated as direct current motors connected to a suitable bus system 35 through suitable control means 36 and 37. Associated with motors 33 and 34 are speed controllers 38 and 39 respectively. Each of these speed controllers is connected to a secondary D.C. bus system 40 through suitable leads. The speed controllers may be of the usual type incorporating automatic field current control arrangements. In connection with the speed controller 38 for the motor 33, there is an additional connection to the output of an amplifier 41. Amplifier 41 is provided with an input control 42 comprising a variable resistor connected to the bus 40, and with a second control resistor 43 having a control arm interconnected with suitable linkage, indicated in dotted lines, connected with the shaft 16 of actuator 19. By this arrangement a signal determined by the setting of control 42 is fed to the speed controller 38 which is indicative of the angle or position of the actuator and its associated tension roll at some point in the fixed operating range of the tension control apparatus. Thus by moving the roll 13, by means previously indicated to a pre-set or null position, the variable controller 42 may then be set in such a manner that no signal will be forthcoming from the amplifier 41 to have any effect on the speed controller 38 when a balanced condition between the controls 42 and 43 exists, this condition existing preferably when the angular position of

the actuator is such that the roll 13 is about mid-way in its fixed operating range.

Operation of the system should be readily apparent to one skilled in the art. With the tension roll out of engagement with the strip 12, a fixed input tension level is introduced into the system by means of the control arm 29 on resistor 28. The signal created thereby will displace the balance valve 22 to the extent that the rotary actuator will be moved in a clockwise direction thereby rotating shaft 16 and support arms 14 and 15 for roll 13 in a clockwise direction. The roll 13 will move upwardly in an arc intersecting the normally straight line path of the strip 12, and will move the strip upwardly causing increasing tension therein. As the roll is moved clockwise in an arcuate path, an extension of the shaft 16 operates through suitable linkage to move the control arm on balance resistor 27 to balance out the input signal and control 28 at a given point in the range of the apparatus. When the system is in operation and the strip material is being driven between the roll stands 10 and 11 across the tension roll 13, in order to maintain the tension constant and consequently the quality of the strip, any deviations in strip tension, as may be caused by varying factors, will be immediately sensed by the transducer 25 and relayed through amplifier 26 to the balance valve 22. Operation of the valve 22 will adjust in one direction or the other the angular position of the actuator 19 and consequently the angular position of the roll 13 in its arcuate path to thereby either increase or decrease the tension as the need may be under certain circumstances. If, due to various tension changing factors in the operation of the mechanism as thus far described, the apparatus should tend to move the roll 13 outside of its operating range, there is provided the ancillary electrical control circuit working through the speed controller 38 to increase or decrease the speed of the motor 33 to thereby vary the speed and consequently the position of the strip 12 moving across the roller 13. In other words, the automatic tension control system involves an electro-hydraulic system which is self-balancing in character in that it is provided with a follow-up means to continually cancel out corrective signals as the tension roll is moved from one null position to another over a fixed range maintaining a constant tension on the strip. In moving along said range under varying conditions, the system is further provided with control circuitry working back through the speed controller for one of the drive roll systems whereby to additionally vary the strip tension to keep the basic automatic system operating within its fixed range.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore to be embraced therein.

What is claimed and desired to be secured by United States Letters Patent is:

1. An automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill comprising a tension roller positioned between said roll stands, means to mount said tension roller for bidirectional movement in a path intersecting the straight line path of movement of said strip material between said roll stands, an hydraulic actuator mechanically connected to and controlling the position of the tension roller, control valve means connected with the actuator to determine both a null position for the actuator and the direction of motion of said actuator from the null position, differential pressure transducing means connected with said actuator, control circuit means for said control valve, means to introduce a predetermined input electrical signal into

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said control circuit means to actuate the valve and move said actuator and the tension roll to place a desired tension on the strip, means in said control circuit mechanically connected with the actuator to balance out the predetermined signal when said actuator has moved proportionately to said input signal, circuit means interconnecting the pressure transducer means with the control circuit means whereby to instantly transmit signals indicating deviations in strip tension through said control circuit means and valve means to said actuator, to correct such deviations, a pair of drive and reducing rolls engaging the strip at each roll stand, electrical drive motor means for said rolls, speed controller means for drive motors whereby the speeds of the motors may be adjusted to predetermined rates in accord with the strip being processed, and electrical means mechanically connected with the actuator and electrically connected with the speed controller of one of the drive motors to adjust the speed of said motor in accord with the position of the actuator.

2. The invention according to claim 1 wherein said input signal introducing means includes an adjustable, non-linear resistor.

3. An automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill, each roll stand including strip engaging rolls and electric drive motors for the rolls which comprises a tension roll positioned between the roll stands, means to mount said tension roll for bidirectional movement in a path intersecting the straight line path of movement of said strip between said roll stands, an actuator to move said tension roll to a predetermined null position, thereby placing a predetermined tension on the strip, control means for controlling movement of said actuator, means interconnecting the actuator and said control means to vary the effect of the control means on the actuator in response to deviations in position of said tension roll from said predetermined null position, speed controller means for each electric drive motor, and electrical means interconnected mechanically with said actuator to establish in one of said speed controllers an electrical condition representative of the position of the actuator and the null position of the tension roll and to vary the speed of the motor through said controller in response to deviations in position of the actuator.

4. An automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill, each roll stand including strip engaging rolls and electric drive motors for the rolls which comprises a tension roller positioned between the roll stands, means to mount said tension roller for bidirectional movement in a path intersecting the straight line path of movement of said strip between said roll stands, an hydraulic actuator to move said tension roll to a predetermined null position thereby placing a predetermined tension on the strip, electrically actuated, hydraulic control valve means for controlling movements of said actuator, electric circuit means connected with said control valve to adjust said valve in accord with a given input signal to establish the null position of the tension roll through said actuator, followup means connected with the actuator to balance out the input signal in the electric circuit means when the null position is reached by the tension roll, electro-hydraulic pressure transducing means connected with the actuator and electrically connected with the electric control circuit to instantaneously convert pressure deviations occurring within the actuator due to variations in strip tension into electric error signals in the control circuit whereby to adjust the valve sufficiently to move the actuator and the roll to a null condition, speed controller means for each electric drive motor, and electrical means interconnected mechanically with said actuator to establish in one said speed controller an electrical condition representative of the position of the actuator and the null position of the tension roll and to

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vary the speed of the motor through said controller in response to deviations in position of the actuator.

5. The invention according to claim 4 wherein said electric circuit means includes an adjustable, non-linear resistor.

6. An automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill comprising tensioning means positioned between said roll stands and movable in a path intersecting the path of movement of said strip material between said roll stands, hydraulic actuator means mechanically connected to the tensioning means for imparting motion thereto, control valve means connected with the actuator means to determine both a null position for the actuator and the direction of motion of said actuator from the null position, differential pressure transducing means connected with said actuator means, control circuit means for said control valve means, means to introduce a predetermined input electrical signal into said control circuit means to actuate the valve and move said actuator and the tensioning means to place a desired tension on the strip, and circuit means interconnecting the pressure transducer means with the control circuit means whereby to instantly transmit signals indicating deviations in strip tension through said control circuit means and valve means to said actuator to correct such deviations.

7. An automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill, each roll stand including strip engaging rolls and electric drive motors for the rolls, which comprises tensioning means positioned between the roll stands and movable in a path intersecting the path of movement of said strip between said roll stands, actuator means to move said tensioning means to a predetermined null position, thereby placing a predetermined tension on the strip, control means for controlling movements of said actuator means, means interconnecting the actuator means and said control means to vary the effect of the control means on the actuator means in response to deviations in position of said tensioning means from said predetermined null position, speed controller means for at least one electric drive motor, and electrical means interconnected mechanically with said actuator means and said speed controller means to vary the speed of said one motor through said controller means in response to deviations in the position of the actuator means.

8. An automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill, each roll stand including strip engaging rolls and electric drive motors for the rolls which comprises a tension roller positioned between the roll stands, means to mount said tension roller for bidirectional movement in a path intersecting the path of movement of said strip between said roll stands, hydraulic actuator means to move said tension roller to a predetermined null position thereby placing a predetermined tension on the strip, electrically actuated, hydraulic control valve means for controlling movements of said actuator means, electric circuit means connected with said control valve means to adjust said valve in accord with a given input signal to establish the null position of the tension roller through said actuator means, follow-up means connected with the actuator means to balance out the input signal in the electric circuit means when the null position is reached by the tension roller, and electro-hydraulic pressure transducing means connected with the actuator means and electrically connected with the electric circuit means to instantaneously convert pressure deviations occurring within the actuator due to variations in strip tension into electric error signals in the control circuit whereby to adjust the valve sufficiently to move the actuator and the roll to a null condition.

9. In an automatic tension control system for maintaining a predetermined tension on a strip of material between the roll stands of a tandem rolling mill including tensioning means movable in a path intersecting the path of the strip and hydraulic actuator means for moving the tensioning means along its path and electric control means for controlling the operation of the hydraulic actuator means, the improvement comprising electro-hydraulic pressure transducing means connected with the actuator means and electrically connected with the electric control means to instantaneously convert pressure deviations occurring within the actuator due to variations in strip tension into electric error signals for application

to the electric control means to cause adjustment of the hydraulic actuator means to counteract the deviations in strip tension.

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RICHARD J. HERBST, *Primary Examiner.*