United States Patent

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[54] **METHOD AND APPARATUS FOR STEERING STRIP MATERIAL THROUGH ROLLING MILLS**
12 Claims, 3 Drawing Figs.

[52] U.S. Cl. 72/8
[51] Int. Cl. B21b 37/00
[50] Field of Search 72/8, 9, 10, 11, 12, 16, 20, 27

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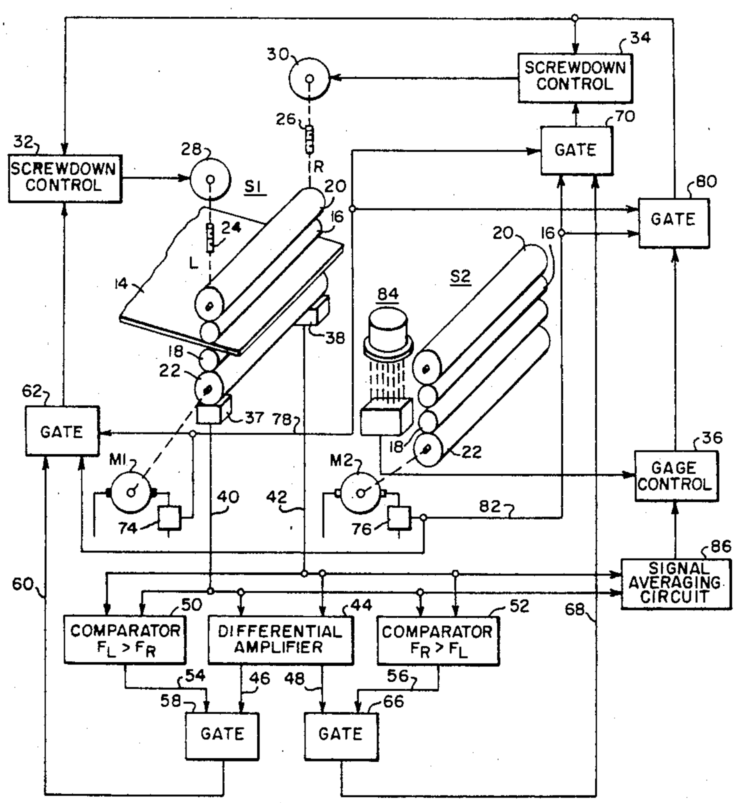
ABSTRACT: Described are a method and apparatus for steering strip material through a rolling mill, particularly when the mill is being threaded, in a manner to prevent the strip from turning off the center line of the mill due to camber (i.e., one edge of the strip being thicker than the other). This is accomplished by adjusting the spacing between the rolls at their opposite ends so as to equalize the roll forces on opposite edges of the strip as it is threaded through the rolls. After the strip is threaded through the rolls and tension applied thereto, either by a succeeding roll stand or by a coiler, the rolls can be adjusted to maintain the spacing between their opposite edges the same or nearly the same. The invention also encompasses strip steering for other purposes as well as strip steering in combination with strip shaping and gage control.



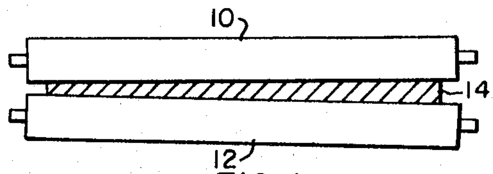


FIG. 1.

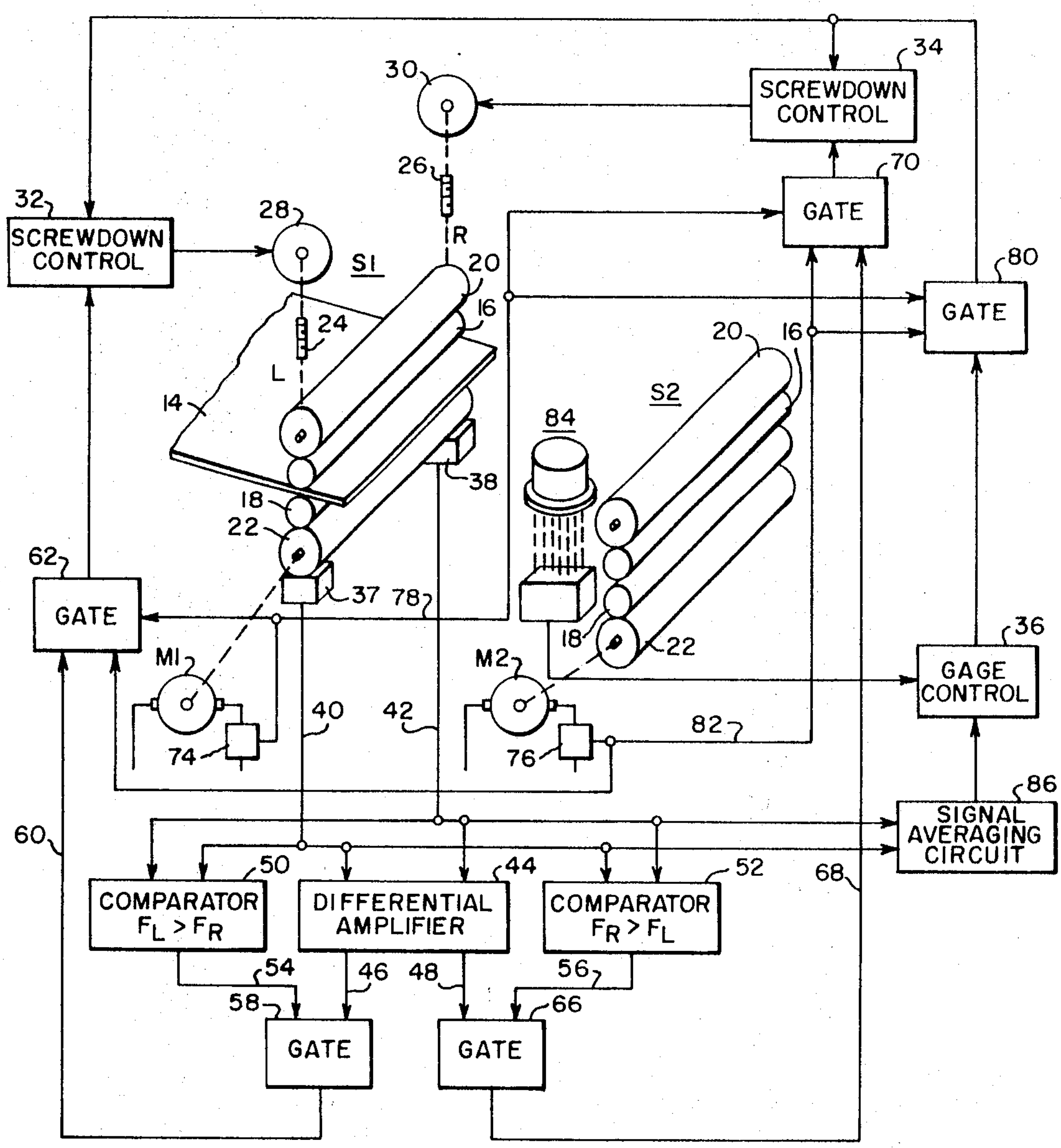


FIG. 2.

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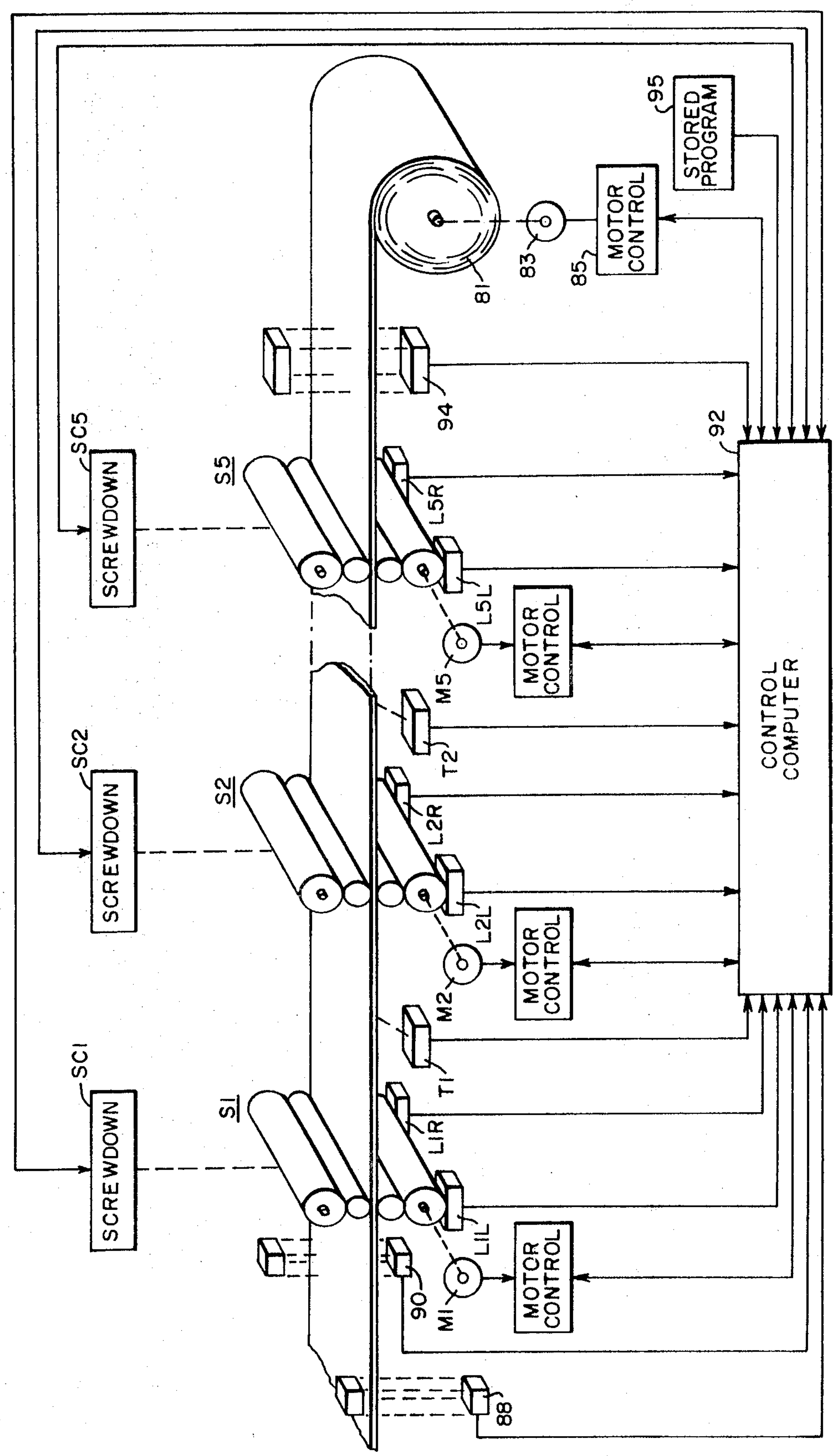
SCREWDOWN
SC1
SCREWDOWN
SC2
SCREWDOWN
SC5
S1
S2
S5
L1R
L1L
L2R
L2L
L5R
L5L
T1
T2
M1
M2
M5
MOTOR CONTROL
MOTOR CONTROL
MOTOR CONTROL
90
88
94
81
83
85
MOTOR CONTROL
95
STORED PROGRAM
92
CONTROL COMPUTER

FIG. 3.

METHOD AND APPARATUS FOR STEERING STRIP MATERIAL THROUGH ROLLING MILLS

BACKGROUND OF THE INVENTION

When a length of metal strip material is threaded through a rolling mill, there is sometimes a tendency for the strip to curve or turn off the mill centerline due to its being thicker at one edge than the other. Normally, the mill stand rolls are leveled, meaning that the spacing between them at their opposite ends is substantially the same. When cambered strip, thicker at one edge than the other, enters such leveled rolls, the rolls attempt to produce a uniform thickness across the width of the strip. This produces a greater roll force at one end of the rolls than at the other end; and since the rolls attempt to take a greater reduction at the thicker edge, the resulting length of the material leaving one end of the rolls tends to be greater than at the other end. This causes a bowed condition in the strip, causing it to turn off the centerline of the mill and making it difficult to thread the strip through a succeeding roll stand of the mill or into a coiler. Considerable productive time is lost due to this tendency of the strip to turn off center during threading operations; and since the productivity of any metal reducing roll mill facility is directly related to the ability of the operating personnel to keep the mill loaded, the tendency of the strip to turn off center is, of course, highly undesirable.

SUMMARY OF THE INVENTION

As one object, the present invention provides new and improved method and means for steering metal strip material through a rolling mill whereby the strip can be caused to pass along a straight line path parallel to the mill center line.

More specifically, an object of the invention is to provide an improved steering system and method for strip material passing through a rolling mill wherein the roll forces at opposite ends of the rolls are measured, and if the roll forces are not the same, indicating a cambered condition of the strip material passing through the mill, the roll spacing at a selected edge of the strip is changed whereby the roll forces are again the same.

Still another object of the invention is to provide a combined strip steering and gage control system for a rolling mill wherein roll force measurements are taken at the opposite ends of the rolling mill rolls and utilized in a combined strip steering, strip shaping and strip gage control system.

A still further object of the invention is to provide a new and improved method for steering strip material through a rolling mill, including strip shaping and strip gage control functions.

In accordance with the invention, means are provided for producing a first electrical signal which varies as a function of the roll force at one end of rolling mill rolls through which strip material passes, and further means are provided for producing a second electrical signal which varies as a function of the roll force at the other end of the aforesaid rolls. The first and second electrical signals are compared to derive a differential electrical signal and this differential signal is used to vary the spacing between one end of the rolls until said roll forces are substantially equal and said differential signal is zero, or some empirically derived offset value near zero.

Further, in accordance with the invention, control of roll forces at opposite ends of the rolls can be utilized to steer the strip through the mill, either under threading conditions or otherwise, to shape the rolls, and to control gage. This is done preferably by means of a computer, responsive to various mill parameters, which regulates the roll forces at opposite ends of the rolls.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings which form a part of this specification, and in which:

FIG. 1 is a schematic illustration of the effect of camber in strip material on rolling mill rolls;

FIG. 2 is a schematic diagram of one embodiment of the present invention particularly adapted for use in rolling mill threading operations; and

FIG. 3 illustrates a computer-controlled combined strip steering, strip shaping and strip gage control system.

With reference now to the drawings, and particularly to FIG. 1, the strip material being rolled between rolls 10 and 12 is identified by the reference numeral 14, the thickness of the strip being greatly exaggerated for purposes of explanation. It will be noted that the right side of the strip is thicker than the left side. Normally, the screwdowns on the opposite ends of the rolls are adjusted such that the spacing between the rolls at their opposite ends is substantially the same. It can be readily appreciated, however, that when a cambered strip, thicker at one side than the other, is threaded through rolls 10 and 12 which are spaced apart in equal amounts at their opposite ends, the roll force at the right side will be much greater than at the left. Furthermore, the strip, in passing through the parallel rolls 10 and 12, will tend to curve or bow off to the left of the centerline of the mill, making it difficult to thread it through a succeeding roll stand or into a coiler.

Apparatus for preventing the strip from turning off the centerline of the mill during threading is shown in FIG. 2. Two rolling mill stands are shown and identified as S1 and S2. Each stand includes a pair of work rolls 16 and 18 and associated backup rolls 20 and 22. At the opposite sides of the stand S1, for example, are screwdown mechanisms schematically illustrated at 24 and 26. These screwdown mechanisms, however, can be replaced with equivalent wedge systems or mechanical linkages designed to regulate the spacing between the rolls, all within the skill of the art. In accordance with well known practice, the screwdown mechanisms 24 and 26, driven by means of motors 28 and 30, control the screwdown force or pressure on journals at the opposite ends of the roll 20. Alternatively, the mechanisms 24 and 26 can be driven by means of equivalent electrical or hydraulic actuators. Screwdown motors 28 and 30, in turn, are controlled by screwdown motor control circuits 32 and 34, respectively. The screwdown motors 28 and 30 are normally controlled by means of a gage control circuit 36 which maintains the spacing between the work rolls 16 and 18 at their opposite ends substantially the same.

Beneath the opposite ends of lower work roll 22 are left and right load cells 37 and 38, respectively. These load cells produce signals on leads 40 and 42 proportional to the roll forces imparted by the respective screwdown mechanisms 24 and 26. The rolls for stands S1 and S2 are driven by drive motors, schematically illustrated as M1 and M2.

The electrical signals proportional to the roll forces at the left and right ends of the rolls are applied via leads 40 and 42 to a differential amplifier 44 which will produce identical outputs on leads 46 and 48 comprising an electrical signal proportion to the difference between the magnitude of the signals on leads 40 and 42. The roll force signals on leads 40 and 42 are also applied to two comparators 50 and 52. Comparator 50 will produce an output signal on lead 54 when the roll force signal on lead 40 is greater than that on lead 42. Similarly, the comparator 52 will produce an output signal on lead 56 when the right roll force signal on lead 42 is greater than that on lead 40. The signals on leads 46 and 54 are applied to a gate 58, the signal on lead 54 acting to enable the gate. Thus, assuming that the left roll force is greater than the right roll force, a signal will appear on lead 54 to enable gate 58 which then passes the differential signal from amplifier 44 to lead 60. Assuming that the gate 62 is enabled, the signal on lead 60 will be applied to the screwdown control circuit 32 to activate motor 28 and raise the screw mechanism 24. As the left screw 24 is raised, the roll force signal on lead 40 progressively decreases until the output of the differential amplifier 44 is zero; whereupon the roll forces at the left and right sides of the rolls are the same. The strip 64 passing between work rolls 16 and 18 of stand S1 now travels to stand S2 along a substantially straight line path.

Similarly, when the right roll force signal on lead 42 is greater than that on lead 40, a second gate 66 will be enabled by a signal on lead 56, thereby passing the signal on lead 48 from differential amplifier 44 to lead 68. Assuming that the gate **70** is enabled, this signal will be applied to the right screwdown control circuit **34** which activates screwdown motor **30** to raise the right screw mechanism **26** until the roll forces are again equal.

A current sensor **74** is provided for the armature of motor **M1** and, similarly, a current sensor **76** is provided for the armature of motor M2. When the strip initially enters the roll bite between work rolls **16** and **18** of stand **S1**, the current through the motor armature will increase. This increase in motor armature current through motor M1 generates a signal on lead **78** which enables the gates **62** and **70**. At the same time, the signal on lead **78** disables gate **80** through which signals from the gage control circuit **36** are applied to the screwdown control circuits **32** and **34**. Thus, once the strip enters the roll pass of stand **S1**, conventional gage control is no longer effective, and the screwdowns are controlled by the output of differential amplifier **44** which causes the roll forces at opposite ends of stand **S1** to be substantially equal in the manner described above.

As the strip **14** progresses through stand **S1**, its forward end will eventually reach stand **S2**; and as it reaches the stand **S2** and enters the roll bite thereof, the current through the armature of motor **M2** will increase, thereby generating a signal on lead **82** which now disables gates **62** and **70** while enabling gate **80** relative to the operation of stand **S1**. At this point, tension is applied to the strip which has now been threaded through both of the stands S1 and S2. Once tension is applied, the strip is more or less forced to travel along a straight line path between the two stands; and when gate **80** is enabled, gage control circuit **36** causes the screwdowns **24** and **26** to again equalize the spacing between the work rolls **16** and **18** at their opposite ends, notwithstanding any chamber which might be present in the strip.

Various types of gage control systems may be utilized such as a more or less simple feedback system wherein the gage at the output of a stand is measured by a suitable thickness gage, such as X-ray gage **84**. However, a roll force gage control system may also be utilized in accordance with the equation:

$$h=S+\frac{F}{M}$$

where

h = delivery gage,
S = screwdown setting,
F = roll force, and
M = slope of the mill spring line (a constant).

If a level roll condition is provided for a given stand, and the input strip has the same thickness at each edge, then the following relationship should prevail:

$$h_L=S_L+\frac{F_L}{M}=h_R=S_R+\frac{F_R}{M}$$

where the subscripts (L) and (R) signify the left and right sides of the rolls, respectively. It will happen, however, that the roll forces at the opposite sides of the mill are not necessarily equal. Accordingly, the signals on leads **40** and **42** are applied to a signal averaging circuit **86** which produces an output signal proportional to the average roll forces on opposite sides of the mill. This signal is then applied to the gage control circuit **36** where the foregoing equation:

$$h=S+\frac{F}{M}$$

is solved to derive a signal proportional is S in relation to a desired delivery gage.

With reference now to FIG. **3**, a computer-controlled circuit is shown which provides strip steering during threading, gage control, load distribution of stand motor, and scheduled successive stand screwdown settings. The rolling mill includes five stands, only stands S1, S2 and S5 being shown for purposes of illustration. At the end of the mill is a conventional coiler **81** driven by motor **83** and controlled by motor control circuit **85**. Each stand is provided with a screwdown mechanism **SC1**, **SC2** and **SC5**, which incorporates means for controlling the roll forces on opposite ends of the rolls for each stand. Left and right roll forces are sensed by load cells L1L, L1R, L2L, L2R, and so on. In order to determine the thickness at the opposite edges of the strip, two input X-ray gages **88** and **90** are employed, the thickness of the material sensed by these gages being fed to a control computer **92** along with screw settings sensed by screwdowns **SC1**, **SC2** and so on. The roll forces are sensed by load cells L1L, L1R, L2L, and so on; and final exit gage is sensed by X-ray gage **94**. Each of the stands is provided with a drive motor **M1** through **M5**, and the tension in the strip between the stands is sensed by tensiometers T1 through T4 which produce electrical signals, proportional to tension, which are fed to computer **92**. The computer **92** is provided with a predetermined stored program **95** in its memory as shown.

With an arrangement such as that shown in FIG. **3**, camber in the entering strip can be sensed by the X-ray gages **88** and **90** by virtue of a variation in the thickness of the strip at its opposite edges. This information, when fed to the master control computer **92**, can be used to adjust the screwdown **SC1**, for example, in order to adjust the spacing between the rolls as desired at their respective ends even before the strip enters the roll bite to maintain the left and right roll forces substantially the same until threading through the first stand and into the second stand is completed as sensed, for example, by a surge in armature current of the motor **M2**.

When the strip enters the second stand **S2**, the computer **92** corrects the strip shape out of the first stand relative to input strip shape errors as sensed by the two X-ray gages **88** and **90** through suitable adjustment of either the right or the left screwdown for stand **S1** as required. At this point, of course, strip steering is no longer a problem relative to the first stand since the strip is held in position by the second stand. If desired, reduced shape corrections can be fed forward into the second stand and even the third and succeeding stands to correct input strip shape errors within the limits of desired steering of the strip.

In the description given in connection with the embodiment of FIG. **2**, and in the embodiment of FIG. **3**, a reduction in gage can be taken during threading while still maintaining the roll forces at opposite ends of the rolls the same, in accordance with the equation:

$$h=\frac{(S_L+S_R)}{2}+\frac{\frac{F_L+F_R}{2}}{M}$$

where the subscripts (R) and (L) again signify the left and right sides of the rolls, respectively. This equation can be solved by the computer to derive S_L and S_R for a desired average output gage, notwithstanding the fact that the thickness of the strip will be greater at one edge than the other and with the opposite roll forces being equal to maintain desired strip steering characteristics.

When the strip enters the windup reel, and the reel motor load therefore indicates that this has happened, and mass flow gage control principles can be used with interstand tensions controlled to determine the delivery thickness from each of the stands, and final gage can be corrected, if necessary, from a reading obtained by the final output X-ray gage **94**. As will be understood, the reading from gage **94** will override computed, desired output gage as determines from mass flow or roll force gage control techniques.

Drive motor speeds are controlled by readings from the tensiometers. The computer **92** can be programmed in advance with known roll bending characteristics as a function of F_L compared with F_R. This can be utilized for roll bending and shape control purposes.

Although the invention has been shown in connection with certain specific embodiments, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention.

I claim:

1. In the method of threading metal strip material through a rolling mill wherein the strip material is reduced in passing between opposed rolls, the steps of rotating said rolls and feeding the end of said strip material into the roll bite between said rolls, and adjusting the spacing between said rolls at the opposite ends thereof as strip material is threaded through said rolling mill until the roll forces at said opposite ends are substantially equal and the strip material leaves the rolls along a substantially straight-line path.

2. In the method of threading metal strip material through a rolling mill wherein the strip material is reduced in passing between opposed rolls, the steps of rotating said rolls and feeding the end of said strip material into the roll bite between said rolls, adjusting the spacing between said rolls at the opposite ends thereof until the roll forces at said opposite ends are substantially equal and the strip material leaves the rolls along a substantially straight-line path, applying tension to said strip material after it has passed through the rolls, and again adjusting said rolls until the spacings between their opposite ends are substantially equal.

3. The method of claim 2, including the step of varying the roll forces on said rolls after tension is applied to said strip material to maintain the gage of said strip material substantially constant across its width as it progresses through said rolls.

4. The method of claim 2, including the step of measuring the gage of strip material at the opposite edges thereof before the strip material enters the roll bite between said rolls, and adjusting the spacing between the opposite ends of said rolls as a function of the measured gage of said strip material at its opposite edges.

5. The method of claim 1, wherein said rolling mill includes a plurality of opposed rolls arranged in tandem and through which said strip material passes, and including the step of maintaining the roll forces at the opposite ends of each set of rolls substantially equal until the strip material enters the bite of the next succeeding pair of tandem rolls.

6. The method of claim 2, including the step of reducing the thickness of said strip material while maintaining said roll forces at the respective opposite ends of said rolls substantially equal.

7. In a rolling mill of the type in which strip material is reduced in passing between opposed rolls, the combination of means for producing a first electrical signal which varies as a function of the roll force at one end of said rolls, means for producing a second electrical signal which varies as a function of the roll force at the other end of said rolls, means for comparing said first and second electrical signals to produce a differential signal, and rolling mill screwdown apparatus responsive to said differential signal and operative only before tension is applied to the strip material passing between said rolls for varying the spacing between at least one end of the rolls until said roll forces are substantially equal and said differential signal is substantially zero.

8. The combination of claim 7, wherein the means for producing said first and second electrical signals comprises load cells disposed at opposite ends of said rolls.

9. The combination of claim 7, including signal gate means for applying said differential signal to said screwdown apparatus, means for generating an electrical signal when tension is applied to the end of strip material passing through said rolls, and means for applying said last-named electrical signal to said signal gate means to disable the same.

10. The combination of claim 9, including means for controlling the gage of strip material passing through said rolls, and second signal gate means responsive to said last-named electrical signal for connecting said gage controlling means to said screwdown apparatus when tension is applied to the end of said strip material passing through the rolls.

11. The combination of claim 7, wherein the means for comparing said first and second electrical signals to produce a differential signal comprises a differential amplifier, a pair of gating devices, means for applying the output of said differential amplifier to both of said gating devices, means for enabling one of said gating devices when said first electrical signal is greater in magnitude than said second electrical signal, means for enabling the other of said gating devices when said second electrical signal is greater than said first electrical signal, a first screwdown mechanism for one side of said rolls, means connecting the output of said first gating device to said first screwdown mechanism, a second screwdown mechanism for the other side of said rolls, and means connecting the output of said second gating device to said second screwdown mechanism.

12. The combination of claim 7, including means for measuring the gage of said strip material at its opposite edges before it passes between said rolls, and computer means operatively connected to said gage measuring means for adjusting the spacing between the respective ends of the rolls.