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CORRECTION OF ROLL POSITIONING IN A ROLLING MILL

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2 Sheets-Sheet 1

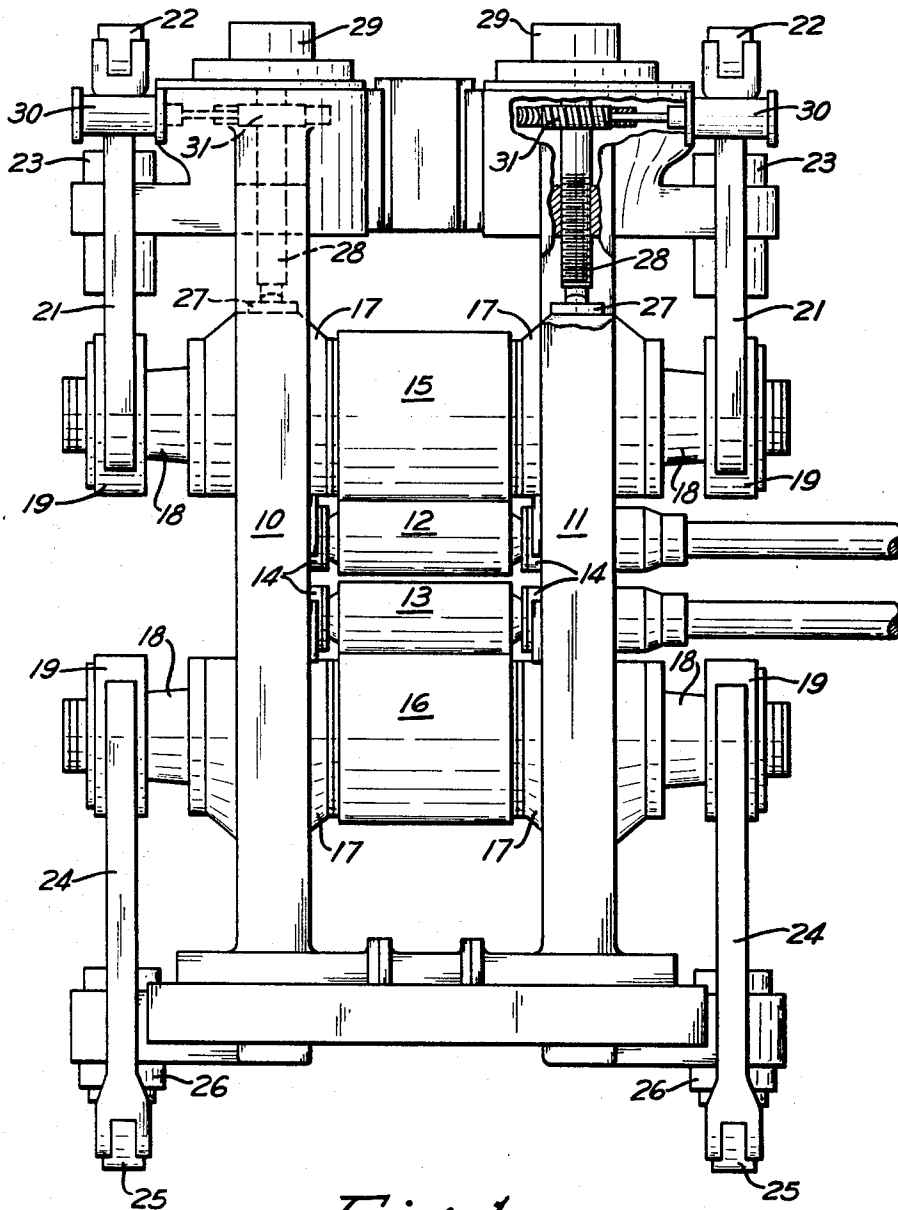


Fig. 1

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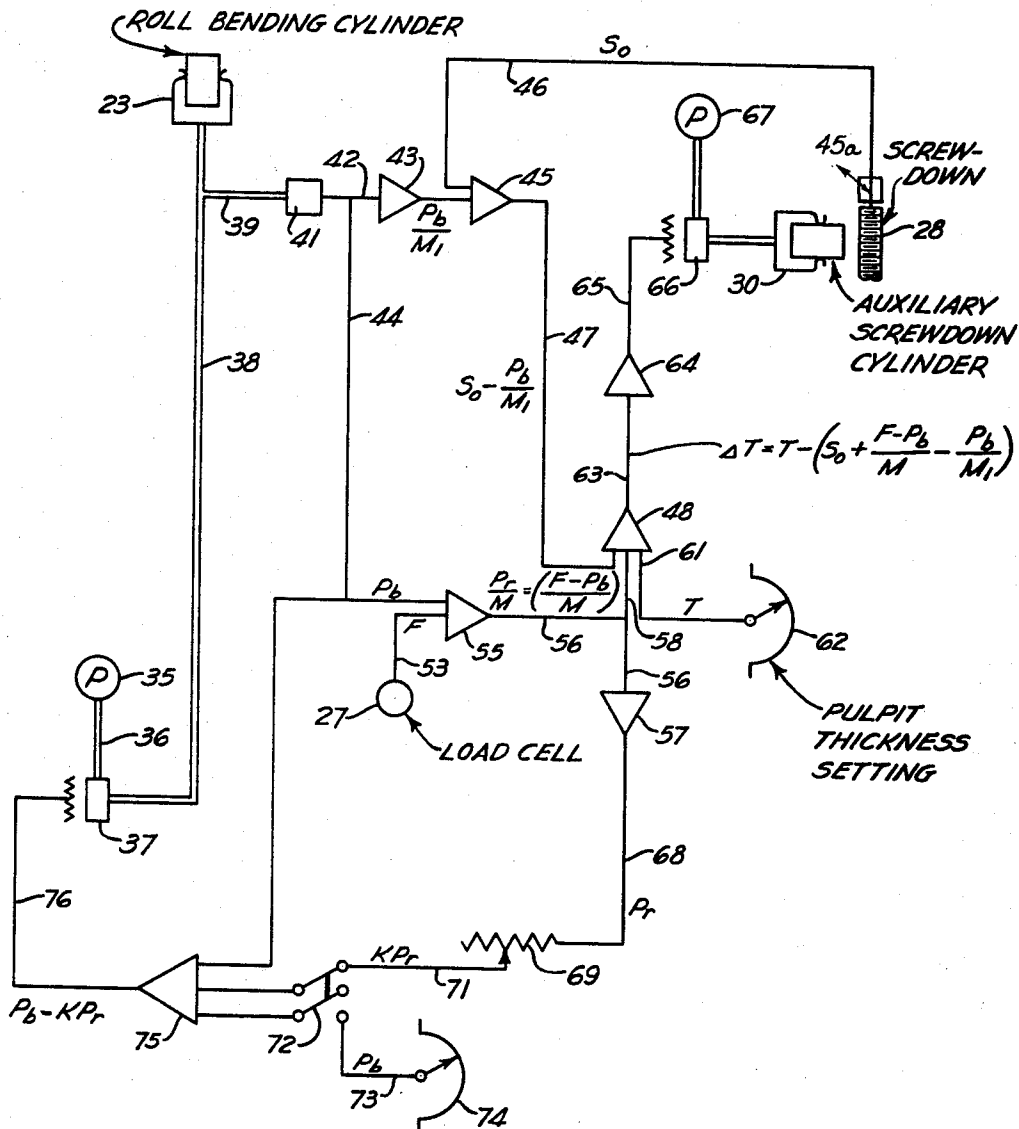
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2 Sheets-Sheet 2



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CORRECTION OF ROLL POSITIONING IN A ROLLING MILL

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ABSTRACT OF THE DISCLOSURE

The present invention provides an automatic longitudinal thickness control for use in a rolling mill which is provided with piston cylinder assemblies for bending the rolls in order to obtain transverse gauge control. The control of the invention provides a load cell for producing a signal representing the total rolling load and a transducer for producing a signal representing the roll bending force. These two signals are combined so that when the rolls are bent in a direction opposite to the normal deflection of the rolls, a signal representing the differences between the rolling load and the bending force is produced. This signal is related to a signal representing the initial setting of the rolls to produce an error signal which is used to adjust the position of the rolls of the mill thereby to obtain constant longitudinal gauge.

This invention relates to a control for automatically controlling the distance between the metal engaging rolls of a rolling mill and, more particularly, is addressed to rolling mills of the type employing means for bending the rolls to compensate for their inherent deflection during rolling.

For purposes of illustration, the present invention will be described in conjunction with the gauge-meter principle for controlling the longitudinal thickness of elongated material, such as disclosed in U.S. Patent No. 2,680,978, which issued to W. C. F. Hesseberg et al. on June 15, 1954. This patent is addressed to what is sometimes referred to in the trade as an AGC system (these letters standing for: automatic gauge control). The method of controlling the thickness of the strip in this system is dependent upon a relationship between the separating force in rolling loads between the rolls developed by the strip passing between them, the roll setting, which is the distance between the rolls when no separating force is involved, and the outgoing thickness of the material. This relationship can be stated as follows: The separating force is proportional to the difference between the outgoing strip thickness and the roll setting, the proportional factor being the elastic constant of the mill commonly referred to as the spring of the mill. Based on this relationship, if any increase in the separating force is accompanied by a decrease in roll gap setting equal to the change in the separating force divided by the mill spring, the outgoing strip thickness will remain constant. Conversely, if any decrease in the separating force is accompanied by an increase in the roll gap setting equal to the change in the separating force divided by the mill spring, a constant outgoing thickness will be obtained.

Of course, it will be understood that the present invention is not necessarily limited to the aforesaid gauge meter system. It applies to other types of gauge control systems, for example, a system wherein the axes of the metal reducing rolls are maintained at a predetermined distance irrespective of the variations in the separating

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force. In this system the rolling mill is subject to a prestressing force exceeding at all times the separating force acting upon the metal reducing roll, in which the value of the prestressing force is automatically changed by a value approximately equal to any change of the separating force, thereby maintaining substantially constant the difference between the prestressing force and the separating force.

The theory of the first system, namely, the gauge meter system may be expressed by the following equation:

$$T = S_0 + \frac{P_r}{M} \quad (\text{Equation No. 1})$$

where T equals the delivery thickness of the strip issuing from the mill, S_0 equals the initial roll gap or screw-down setting, P_r represents the rolling load and M the spring or modulus of the mill. As demonstrated by this formula, in order to make T constant when the rolling load P_r is variable, the value S_0 (roll gap) must be changed to compensate for changing the rolling load. Thus, the gauge meter principle corrects the position of the screws of the mill to make allowances for variation in the factor P_r/M so that T is theoretically held constant.

This relationship, however, may be drastically and detrimentally influenced in those mills which provide means for imposing a force or moment on the rolls to resist or compensate in whole or in part for the deflection of the rolls under the rolling loads. Such devices may take a number of different forms and may operate on the backup rolls and/or work rolls of the mill. For purposes of describing the present invention, force or moment-applying means applied to the backup rolls of a 4-high mill for producing strip, sheet or plate will only be considered. In this connection, such means will sometimes be referred to hereinafter as a "rollbender."

As previously mentioned, when a roll bender is used in conjunction with a gauge meter system an additional roll gap setting correction has to be made and a system for carrying out such a correction is a subject matter of the present invention. To cite one area of the problem, keeping in mind the mill in question includes both an AGC system and roll bender system, let it be assumed that the roll bender is called upon to impose upon the rolls an increased force to "add crown to the roll" in order to improve the flatness of the strip. Of course, the roll bender could be employed to decrease the roll crown wherein in the following analysis the roll bender pressure is exerted in the opposite direction. In the first case, in addition to subtracting the force developed by the roll bender from the load cell provided in the gauge meter system, it has been discovered that it is necessary to make an additional correction in the screwdown setting of the mill. This additional correction is brought about by the fact that the increased bending load generated by the roll bender results in a decreasing of the distance between the cooperative surfaces of the metal reducing rolls, which causes the signal from the load cell, minus the force from the roll bender, to increase causing, in turn, a false signal to the screwdown, which would result in the screwdown moving the rolls closer together. This can be more clearly understood in referring to Equation No. 1. As previously noted, the bending of the rolls raises the value of the factor P_r/M . Under these circumstances normally the initial roll setting S_0 could be changed commensurate with the increased value of the factor P_r/M in an effort to maintain the delivery thickness T constant. This, of course, is directly contrary to what must be done, as noted above.

At this point it is believed helpful to express algebraically the relationship that an increase or decrease in the

force of the roll bender has on the load cell reading of the gauge meter system, which is expressed as follows:

$$T = S_0 + \frac{F - P_b}{M} \quad (\text{Equation No. 2})$$

It is to be understood in this equation that the rolling load equals the load cell reading F minus the roll bender load P_b and wherein, as the equation points out, the force of the roll bender P_b is subtracted from the load cell reading, if T , the delivery thickness, is to be maintained constant, and the influence of the roll bender force of the other components of the mill is to be disregarded for the present moment.

In now turning to the relationship that the roll bender force has on the gauge control meter, it might be helpful first to state this relationship algebraically, wherein we have:

$$T = S_0 + \frac{F - P_b}{M} - \frac{P_b}{M_1} \quad (\text{Equation No. 3})$$

wherein T and S_0 again equal the delivery thickness of the strip and the roll gap setting, respectively, the factor $F - P_b/M$ equals the mill deflection under the rolling loads only, and the factor P_b/M_1 equals the deflection of certain mill parts, which influences the roll gap due to changes in bending cylinder load. Consequently, M_1 is the modulus of certain mill parts, namely: backup rolls deflection, elastic stretch of the housings, compression of the mill screws, screwdow boxes, and the backup roll chocks. Since the backup roll deflection is negative and the other deflections are positive, M_1 represents the algebraic sum of these deflections and while usually negative could, with certain mill proportions, become positive.

Should the roll bender force be applied in the opposite direction to reduce the crown, Equation No. 3 will be rewritten as

$$T = S_0 + \frac{F + P_b}{M} + \frac{P_b}{M_1}$$

The two equations can be expressed in a single equation as:

$$T = S_0 + \frac{F \pm P_b}{M} + \frac{\pm P_b}{M_1}$$

Thus, the present invention is addressed to a system for correcting or compensating for the influence that the bending of one or more rolls of the mill has on a gauge control system or a system for maintaining the distance constant between the cooperative metal reducing rolls. More particularly, the present invention refers to a fluid electric control system for use in conjunction with a strip thickness control system. Still further, the present invention provides the control system for compensating for the influence that corrective roll bending has on a strip thickness controlling system, wherein the roll benders are tied in with a means for determining the rolling loads of the mill so that they will be automatically operated in accordance with an increase or a decrease in the rolling loads. These objects, as well as other features and advantages of the present invention, will be more clearly understood when the following specification is read along with the accompanying drawings of which:

FIGURE 1 is an elevational view, partly in section, of a 4-high rolling mill incorporating means for bending the backup rolls thereof and an auxiliary screwdow means for effecting a quick adjustment of the roll gap of the mill, and

FIGURE 2 is a fluid electric diagram for carrying out the present invention, certain elements of the mill shown in FIGURE 1 also being represented in the diagram for clarity's sake.

With reference first to FIGURE 1, there is shown a pair of mill housings 10 and 11 having the customary windows, not shown, into which there are received cooperative work roll assemblies 12 and 13 which forms a rolling

pass, these assemblies have the customary bearing chocks 14 at their outer ends which are received in the mill housings 10 and 11. Each work roll 12 and 13 is backed up by relatively larger backup rolls 15 and 16, thus constituting the mill a 4-high mill. The backup rolls, in the customary manner, are provided with bearing chock assemblies 17 at their outer end which are also received in the housings 10 and 11.

To incorporate the roll bending feature, previously mentioned, to the backup rolls 15 and 16, these rolls are provided with extended necks 18 which receive outboard bearings 19, to each side of which there are connected in the case of the upper backup rolls 15 parallel links 21 extending upwardly which are received in a yoke 22, the yokes itself being connected to a piston cylinder assembly 23. With respect to the lower backup roll 16, it likewise has connected to each of the bearings 19 downwardly extending parallel links 24 which are joined together by a yoke 25, the yoke being connected to the piston of a piston cylinder assembly 26. As noted in FIGURE 1, the cylinders 23 and 26 are carried by portions of the housings 10 and 11, the arrangement being such that equal and opposite forces are generated by the cylinders with respect to the supporting portions of the housing and such forces are not imposed on the housings themselves.

Again referring to the upper backup roll 15, its chocks 17 carry load cells 27 which are engaged by mill screws 28 which are adapted to be rotated by a primary screwdow referred to as 29 of customary mill design and a secondary quick-acting auxiliary screwdow which consists of a piston cylinder assembly 30 which is adapted to traverse the worms 31 of the screwdow according to the disclosure and teaching of U.S. Patent No. 3,104,567, which issued to M. P. Sieger on Sept. 24, 1963. As previously noted, under the rolling loads the rolls 12, 13, 15 and 16 being mounted as end-supported beams inherently deflect, which causes a non-uniform cross section gauge in the material issuing from the mill. To alleviate this condition, the backup rolls of the illustrated mill are designed to be deflected in the directions opposite to their inherent deflections by the operation of the cylinders 23 and 26. It must be borne in mind that the cylinders 23 and 26 may also be employed to improve the flatness of the material issued from the mill as distinguished from its cross sectional thickness thereof.

With reference now to FIGURE 2, there is illustrated a fluid electric diagram in which to better understand the diagram, the factors involved in the aforesaid Equation No. 3 have been shown by legend. In describing the various elements of the electrical system, it might be helpful to first identify the roll bending cylinder 23, one of the screws 28 and one of the auxiliary screwdow adjusting cylinders 30 that are illustrated in FIGURE 1 and, finally, one of the load cells 27. Starting then with the roll bending cylinder 23, there is provided a pump 35 which feeds fluid by virtue of a line 36 to a servo-valve 37 that controls the volume of fluid entering the roll bending cylinder 23. As shown the servo-valve is connected to the cylinder 23 by a line 38. In the vicinity of the cylinder 23 a line 39 is joined to the line 38 on the one hand and to a transducer 41 on the other which produces an electrical signal directly proportional to the pressure in the hydraulic line 38. On the right-hand side of the transducer 41 there are electrical lines 42 and 44, the latter being referred to later on, the former being connected to an amplifier 43 where the signal P_b is combined with a signal representing $1/M_1$ to produce an electrical signal representative of the value P_b/M_1 which is indicated on the diagram. This value is fed to an amplifier 45 which, in addition, receives a signal of a position indicator 45a representative of the value S_0 from a line 46 which is also identified on the diagram. Thus, a signal is produced from an amplifier 45 representing the algebraic expression of Equation No. 3, namely

$$S_0 - \frac{P_b}{M_1}$$

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as the diagram illustrates. This value is electrically transported by a line 47 to an amplifier 48.

With reference now to one of the load cells 27, by a line 53 the load cell feeds a signal representative of the total load F to an amplifier 55 which also receives a signal P_b from the line 44. The amplifier 55 combines with each of these two signals a $1/M$ factor which is a representation of the mill modulus. These two factors are also, for convenience, illustrated on the diagram. The amplifier 55, as indicated also on the diagram, produces a signal representative of

$$\frac{P_r}{M} = \left(\frac{F - P_b}{M} \right)$$

the factor Pr/M is fed by a line 56 to an amplifier 57, whereas the factor

$$\frac{F - P_b}{M}$$

is fed by a line 58 to the amplifier 48. The amplifier 48 also receives a signal representing the value T (the required thickness) from a line 61 which value, as represented on the diagram, is set by a pulpit thickness setting device 62. The amplifier 48 thus receives at its input the values T , P_r , M and

$$S_0 - \frac{P_b}{M_1}$$

and produces a signal representative of the gauge error,

$$\Delta T = T - \left(S_0 + \frac{F - P_b}{M} - \frac{P_b}{M_1} \right)$$

which it feeds in the form of a signal by a line 63 to an amplifier 64. The amplifier 64 sends on the signal by a line 65 to a servo-valve 66 associated with the piston cylinder assembly 30, the cylinder assembly having a pump 67 which is shown on the diagram. The screwdown, under the influence of the signal received from the amplifier 64, will cause an adjustment of the screw 28 so that S_0 will be changed until $\Delta T = 0$.

As previously noted, it is sometimes desirable to automatically operate the roll bending cylinders 23 in accordance with a change in the rolling load so that the deflection of the backup rolls 15 and 16 will be automatically controlled pursuant to the particular rolling pressure being experienced. The diagram in FIGURE 2 illustrates a system for providing for this. Turning again to the amplifier 57, it will be noted that it sends a signal representative of P_r over a line 68 to a potentiometer 69 where a constant factor "K" is added to the value P_r to produce a signal KP_r , which is shown on the diagram. The need for introducing the value K arises from the fact that the bending force P_b should be maintained equal to KP_r , where as previously noted, P_b is the bending force of the cylinders 23 and 26 and P_r is the rolling load. The proportional factor between the roll bending force and the rolling loads, which will vary as the rolling loads vary, is taken care of by a potentiometer 69. The signal from the potentiometer 69 is sent by a line 71 to a switch 72 which has two contact legs, one that contacts the line 71 and the other, when the first contact is broken, contacts a line 73 that runs to a manual reference setting 74 for the factor P_b . In this way when the switch 72 is disconnected from the rolling loads as carried by the line 71, the pressure is still maintained in the cylinder 23, which without the reference signal P_b would not happen. The switch 72 feeds a signal to an amplifier 75 which produces a signal representative of the summation $(P_b - KP_r)$, which, in turn, is fed by a line 76 to the servo-valve 37 for controlling the pressure of fluid admitted to the bending cylinders 23 and 26, so that the output signal from the amplifier 75 is maintained substantially zero, with the result that $P_b = KP_r$.

The operation of the diagram shown in FIGURE 2 will now be briefly explained. Let it be assumed that the

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setting 62 relating to the desired thickness and the P_b manual reference setting 74 have to be adjusted to give the proper signal T and P_b , respectively. Let it further be assumed that material is being reduced and that the load cells 27 have just received a signal indicating that the rolling loads of the mill have increased. This, of course, will feed a signal to the amplifier 55, and hence to the amplifier 57 representative of the value P_r or the rolling load, which signal will be received by the amplifier 75 and the amplifier 75 will cause an operation of the servo-valve 37 associated with the roll bending cylinders 23 and 26 to increase the pressure and effect a greater compensative deflection of the backup rolls 15 and 16. This increased pressure in the line 38 feeding to the roll bending cylinders 23 will be detected by the transducer 41, whereby the amplifier 43 associated therewith will produce a value representative of the factor P_b/M_1 which will be fed to the amplifier 45 where it is joined with the value S_0 representative of the screwdown setting. These combined values then, as indicated previously, are received by the amplifier 48, and at the same time this amplifier 48 will receive a signal from the amplifier 55 representative of the value

$$\frac{F - P_b}{M}$$

The amplifier 48 also receives a signal representative of the desired thickness T from the pulpit setting device 62. The amplifier 48 will then produce a signal representative of the gauge error

$$\Delta T = T - \left(S_0 + \frac{F - P_b}{M} - \frac{P_b}{M_1} \right)$$

which signal will be received by the servo-valves 66 associated with the auxiliary screwdown mechanism 30 to effect an operation of the screws 27, whereby ΔT will be made equal to zero.

It will be appreciated that the electrical amplifiers illustrated in the diagram shown in FIGURE 2 operate in accordance with well-known principles as illustrated in a publication by Korn and Korn, entitled, "Electric Analog Computers," published by McGraw-Hill, 1952.

In accordance with the provision of the patent statutes, I have explained the principle and operation of my invention and have illustrated and described what I consider to represent the best embodiment thereof. However, I desire to have it understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. In an apparatus such as a rolling mill or the like, having a pair of processing rolls forming a rolling pass and between which material to be processed passes and wherein said rolls are normally deflected away from the material due to the pressure developed between the rolls during the processing,
 - means for adjusting one of the rolls relative to the material,
 - means associated with the rolls for exerting a force to bend at least one of the rolls in a direction opposite to the normal direction of deflection of said one roll, a control including:
 - means for producing a first signal representative of the elastic changes of at least some of the parts of the apparatus subject to the force exerted by the force-exerting means,
 - means for producing a second signal representative of the change in the distance between the rolls caused by the rolling pressure developed therebetween,
 - the sum of said first and second signals representing the total change in the distance between the rolls,
 - means for receiving said first and second signals and producing a third signal representing the difference between the rolling pressure and the force exerted to bend said one roll, means for producing an additional signal representing the rolling pass setting be-

fore said rolls are subject to any rolling pressure, and means for receiving said third signal and said additional signal for controlling said means for adjusting one of said rolls to correct for the change in distance between the rolls.

2. In an apparatus according to claim 1 wherein said means for producing said second signal produces a signal representative of the elastic change of some of the mill parts of the apparatus subject to the pressure developed between the rolls.

3. In an apparatus according to claim 2, means for producing a fourth signal representative of the amount of change required to be exerted by said force-exerting means as the pressure between the rolls changes, and

means connected to said force-exerting means controlled by said fourth signal to effect operation of the force-exerting means pursuant to said fourth signal.

4. An apparatus according to claim 3 wherein said fourth signal represents the pressure developed between the processing rolls,

means for multiplying a substantially constant value with said fourth signal, said constant value representing a proportional factor between the force-exerting means and the pressure developed between said rolls, and

means for receiving said modified fourth signal producing a fifth signal representative of the change required to change said force-exerting means commensurate with a change in the pressure developed between the rolls.

5. An apparatus according to claim 2 wherein said control is adapted to compute ΔT from the following equation:

$$\Delta T = T - \left(S_0 + \frac{F \pm P_b}{M} + \frac{\pm P_b}{M_1} \right)$$

wherein

ΔT =gauge error

T =desired material thickness

S_0 =relative position of the processing rolls

F =pressure developed between the rolls

P_b =the force exerted by said force-exerting means,

M =modulus of parts subject to pressure developed between the rolls, and

M_1 =modulus of parts subject to the force-exerting means, and

means controlled by said control means for operating said means for adjusting said one roll to make $\Delta T=0$.

6. An apparatus according to claim 2 wherein said roll-adjusting means comprises a screwdown,

said means for exerting a force to compensate for roll deflection comprises piston cylinder assemblies arranged to impose bending moments on the rolls,

said means for providing said additional signal representing the setting of the screwdown which reflects the no load separation between the rolls,

means for receiving said first, second, third and additional signals and producing a fifth signal representing the amount the rolls are separated by the pressure developed between the rolls and the force-exerting means, and

means for operating said screwdown to position said one roll to compensate for changes in roll separation.

7. An apparatus according to claim 2 wherein a means for adjusting said one roll includes:

a primary screwdown for initially establishing the relative position between the rolls and a secondary screwdown for effecting any change in the position of the roll as required by said control means.

8. In an apparatus according to claim 1 wherein said means associated with said one roll is adapted to bend said one roll in the same direction as the normal direction of deflection of said roll, and wherein said means for producing said third signal produces a signal representing the sum of the rolling pressure and the force exerted to bend the roll when said roll is bent in the same direction as the normal direction of deflection of said one roll.

9. In an apparatus such as a rolling mill or the like, having a pair of processing rolls forming a rolling pass and between which material to be processed passes and wherein said rolls are normally deflected away from the material due to the pressure developed between the rolls during the processing,

means for adjusting one of the rolls relative to the material,

means associated with the rolls for exerting a force to bend at least one of the rolls in the same direction of the normal direction of deflection of said one roll, a control including:

means for producing a first signal representative of the elastic changes of at least some of the parts of the apparatus subject to the force exerted by the force-exerting means,

means for producing a second signal representative of the change in the distance between the rolls caused by rolling pressure developed therebetween,

the sum of said first and second signals representing the total change in the distance between the rolls,

means for receiving said first and second signals and producing a third signal representing the sum of the rolling pressure and the force exerted to bend the rolls,

means for producing an additional signal representing the rolling pass setting before said rolls are subject to any rolling pressure, and

means for receiving said third signal and said additional signal for controlling said means for adjusting one of said rolls to correct for the change in distance between the rolls.

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