

Jan. 20, 1970

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3,490,256

CONTROL FOR OBTAINING CONSTANT GAUGE IN A ROLLING MILL

Filed Jan. 24, 1967

4 Sheets-Sheet 1

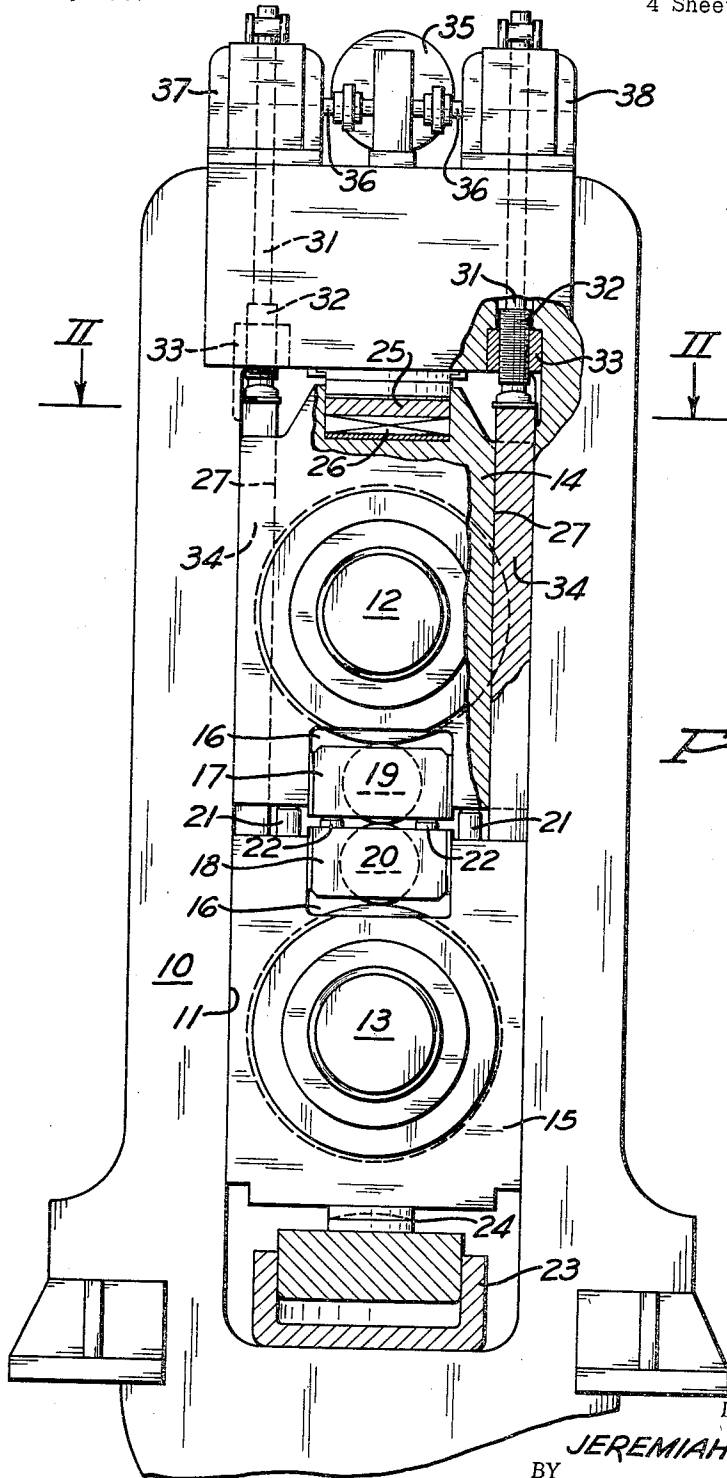


Fig. 1

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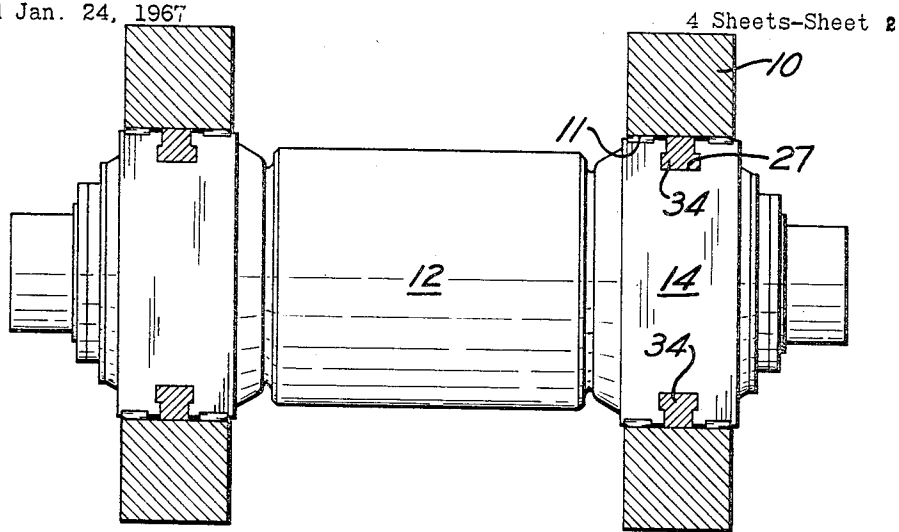


Fig. 2

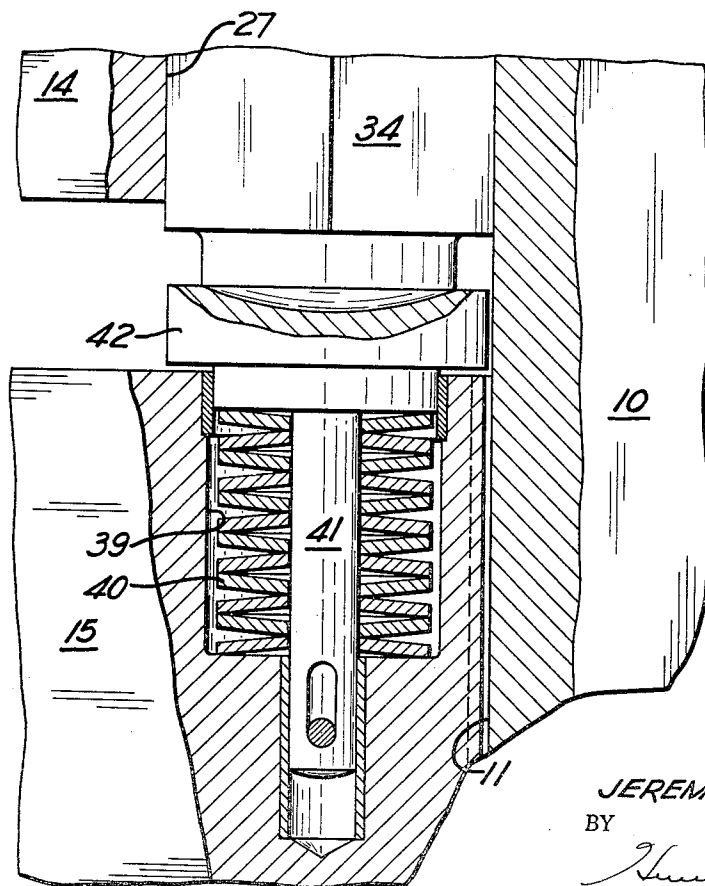


Fig. 3

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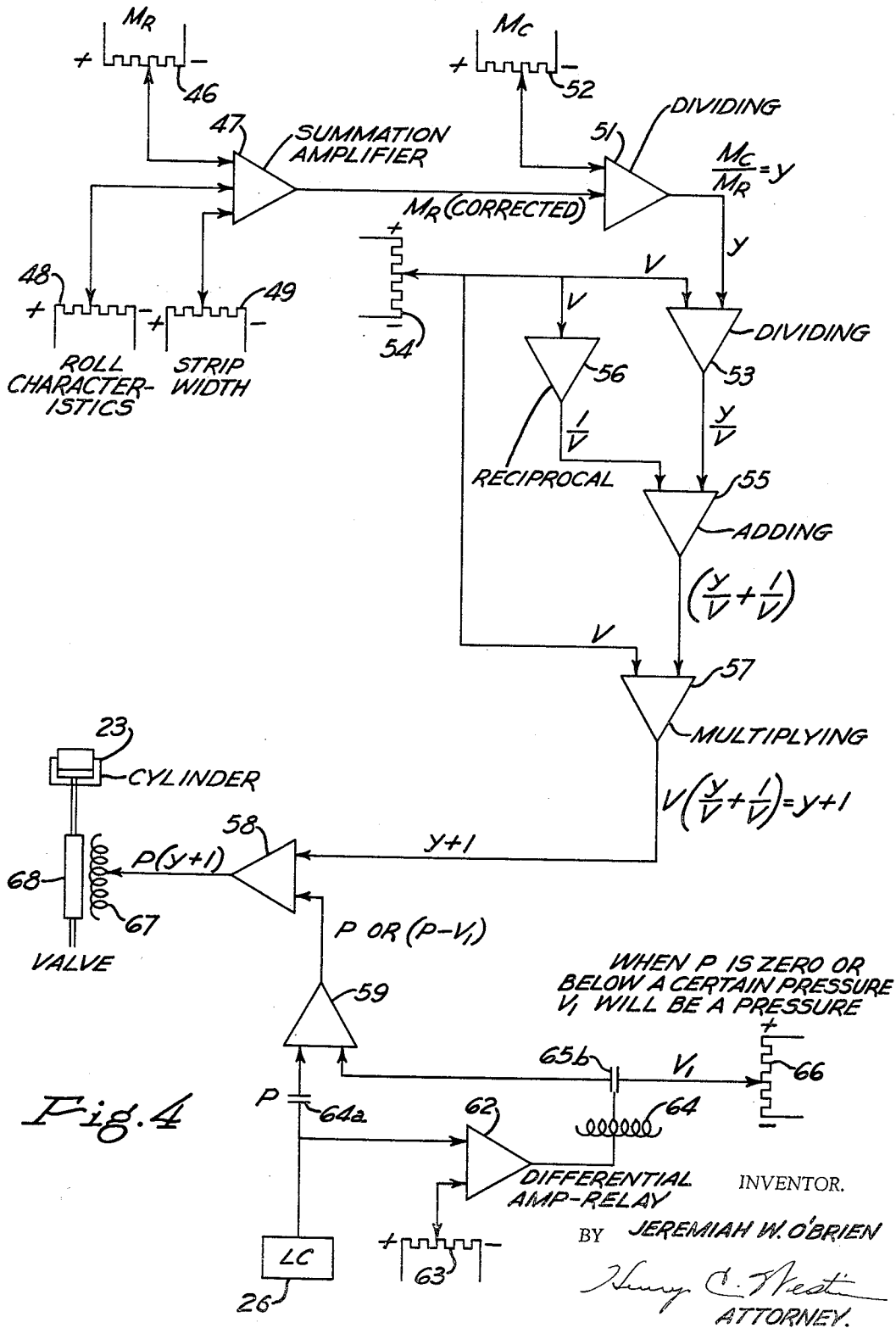
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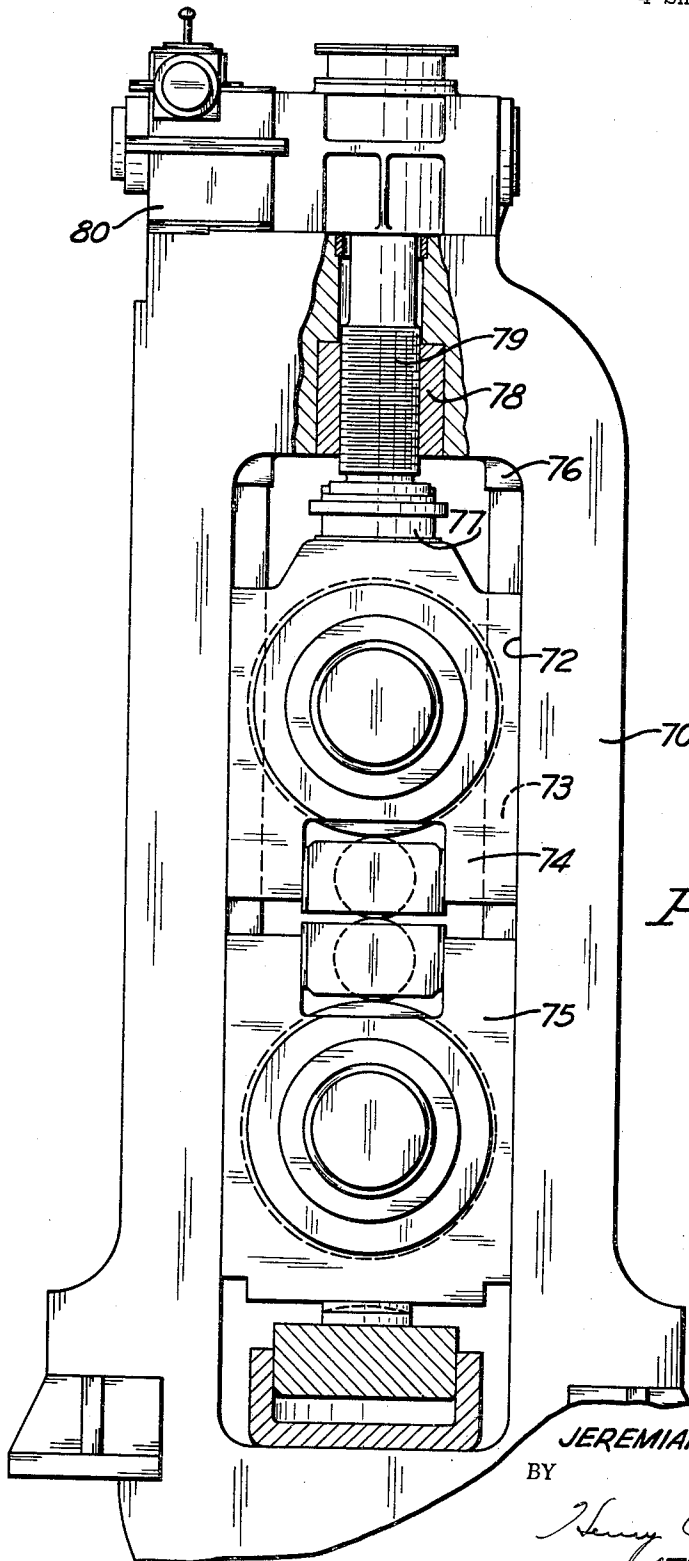


Fig. 5

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CONTROL FOR OBTAINING CONSTANT GAUGE IN A ROLLING MILL

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5,974/66

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U.S. Cl. 72-6

14 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to an improvement in rolling mills and, more particularly, to an improved mill and control for producing very accurate gauge workpieces, such as strip, plate and the like.

The present invention provides for an improved rolling mill and control thereof which is characterized by being very economical to manufacture and maintain and capable of giving trouble-free operation even in the difficult environment of a rolling mill plant.

In the present invention there is provided a method and apparatus for maintaining the roll gap of a mill constant, thereby substantial constant gauge can be obtained and wherein the roll separating forces created during rolling are adapted to be transmitted to a first group of related mill parts, including first and second reducing rolls, which parts when subjected to varying separating forces have a variable effective length, the change of which represents an undesirable change in the roll gap by reason of the displacement of the rolls and wherein a controlled force is transmitted to a second group of related mill parts which, when subjected to such a force, has a variable effective length, the algebraic sum of said controlled force being exerted in a direction opposing the separating force and being greater than the separating force, and wherein the controlled force is varied in a manner to change the effective length of the second group of mill parts to compensate for the change in length of the first group, thereby to move the second roll relative to said first roll to maintain the roll gap substantially constant.

In the foregoing object the controlled force is controlled by the following formula:

$$F=(Y+1)P$$

where F equals the controlled force, Y equals the proportionality of the moduli or spring coefficient of the first and second groups of mill parts and P is the rolling load.

In furtherance to the aforesaid object of the present invention, means separate from the force applicator is provided to set the initial desired gap of the mill rolls.

It is a further object of the present invention to provide a roll gap control for a rolling mill or the like having a pair of cooperative metal working rolls which constitute at least part of a first group of mill parts, which parts have a variable effective length when subject to varying separating forces, means for producing a first signal representative of the separating force generated by said rolls, a second group of mill parts having a variable effective length when subject to a varying controlled force, a con-

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trolled force of a magnitude greater than the separating force and in a direction opposing the separating force and adapted to move a roll of the mill, means for producing a second signal representative of the proportionality of the moduli of said first and second groups of mill parts, means for receiving said first and second signal and producing a third signal representative of the change in the roll gap by reason of the changes in the effective lengths of the said two groups of mill parts which, in turn, represents the controlled force necessary to vary the effective length of the second group of mill parts to compensate for the change in effective length of the first group of mill parts, thereby to maintain the roll gap of the mill substantially constant, said third signal being used to control the operation of said controlled means.

In furtherance to the aforesaid object of the present invention there is provided in said second group of mill parts force transmission bars engageable with a roll assembly on the side of the mill on which the pressure means is located, said bars being unconnected with the roll assembly on the opposite side of the mill, but engaging with said housing on that side and adapted to resist the controlled force.

It is a further object of the present invention to provide readily yieldable means in said second group of parts whereby said second group is characterized by a low modulus or spring coefficient.

It is a still further object of the present invention to provide an improved rolling mill wherein the initial roll gap of the rolls is set by a very simplified, trouble-free screwdown arrangement which, in one form, as adapted to operate with a 4-high rolling mill, takes the form of four parallelly arranged rotatable screws, a pair of each being mounted in one of two housing posts, which screws either engage force transmission bars located between the housings and one of the backup chocks of the mill, in a manner to effect movement thereof, which movement establishes the initial gap of the working rolls.

BRIEF SUMMARY OF INVENTION

There has, in recent years, been an increasing and concerted effort to improve the tolerance of the workpiece produced by a rolling mill. U.S. Patent Nos. 2,726,541, 3,197,986, and 3,208,251 are illustrative of recent patents that have been addressed to this objective. These and other known arrangements for improving accuracy of gauge have been found to involve some serious disadvantages and limitations. For one thing, many of them are extremely expensive, both from a manufacturing and a maintenance standpoint. Some are extremely difficult to maintain in effective operating condition due to the environment in which a rolling mill must operate and are not conducive to trouble-free performance for any appreciable duration. A further disadvantage of some of the present systems has to do with the fact that there is a significant lag between the time the need for gauge correction is discovered and the time it takes to make the necessary correction in resetting of the rolls and/or adjustment of the tension.

DRAWINGS

These objects, as well as other novel features and advantages, will be better appreciated when the following

description is read along with the accompanying drawings, of which:

FIGURE 1 is an elevational view, partly in section, of one embodiment of the present invention;

FIGURE 2 is a sectional view taken on lines II—II of FIGURE 1;

FIGURE 3 is a modification of the mill shown in FIGURES 1 and 2, showing the employment of an inherent elastic member in the group of mill parts associated with the prestressing means;

FIGURE 4 represents an electrical diagram of a control for use in practicing the present invention in the form illustrated in the previous figures; and

FIGURE 5 is an elevational view, partly in section, of a still further embodiment of the present invention.

DESCRIPTION OF INVENTION

With reference first to FIGURES 1 and 2 which illustrate the preferred arrangement of the present invention, there is illustrated a rolling mill consisting of a pair of upright housings, one of which, 10, is only illustrated, it being understood that the housings with their components are identical in structure. The housing 10 has a window 11 into which there is received upper and lower backup rolls 12 and 13 having chocks 14 and 15, respectively, the chocks having opposed openings 16 into which there are received the chocks 17 and 18 of work rolls 19 and 20, respectively. The backup chocks 14 and 15 are urged away from each other in the usual manner by roll balance piston cylinder assemblies 21, as are the working rolls by roll balance piston cylinder assemblies 22. The lower backup chock is associated with a force applicator in the form of a piston cylinder assembly 23 located at the bottom of the mill having a piston 24 which engages the lower surface of the lower backup chock 15 through a spherical connection. The piston cylinder assembly is connected to a fluid power source capable of exerting a variable force in excess of the separating force.

With respect to the upper backup chock 14 of the housing 10, it is separated from the housing post by a breaker block 25 and a load cell 26, which could be any of a number of commercial units designed to measure the separating force of the mill.

As indicated previously, it is an important feature of the present invention to provide a novel and simplified screwdown arrangement for initially setting the gap of the working rolls 19 and 20, in which regard it will be noted in FIGURES 1 and 2 that the upper backup chock 14 is provided with parallel openings 27, a continuation of which extends through the top of the mill and through which are inserted rods 31, the lower ends having threaded portions 32 which are received in nuts 33 non-rotatably mounted in the housing 10. The lower ends of the rods 31 engage elongated compression bars 34 which are received in the chock opening 27 and extend to the lower backup chock 15, which they forcibly contact. The upper end of the rods 31 are drivenly associated with a common motor 35, the motor driving through a set of spindles 36 which are associated with worm-wheel units 37 and 38 which serve to transmit the power of the motor to the rods 31. It will be noted that a similar motor-wheel arrangement will be provided for the other housing and that the gear units will be interconnected to assure synchronous operation of the screwdown arrangement for both housings.

As previously noted and as will more fully be explained hereinafter, it is the primary object of the present invention to provide a novel rolling mill construction and control for obtaining substantial constant gauge by maintaining the gap between the working rolls substantially constant. Thus, the present invention contemplates a mill construction and control that will automatically compensate for the elastic change in the characteristics of the mill components which takes place as the separating force changes. It should be noted in this respect, in view of the fact that the piston cylinder assembly 23 is located on the

inside of the housing 10 to directly receive the separating force of this mill, that any elastic change in the housing due to a change in the separating force will be automatically compensated for by a displacement of the piston of the cylinder and, therefore, such elastic change need not be considered in determining the degree of compensation needed to maintain the roll gap constant.

The present invention stems from a discovery that the roll gap of the mill can be maintained constant automatically if various parts of the mill are arranged to function in interrelated but different groups, one group being subject to the separating force which will result in an elastic change of its effective length and wherein the other group is subject to a controlled force, which force is applied in a direction opposing the separating force and of a magnitude sufficient to change the effective length of the second group of mill parts an amount sufficient to compensate for the change in length of the first group of mill parts. It will be readily appreciated, and more so from the subsequent remarks, that a distinct advantage can be realized in designing the mill so that the elastic characteristic of the second group of mill parts is such that not only will sufficient capacity be available to correct for the elastic change of the first group of mill parts, but be of a sufficient low value to allow the screwdown mechanism and the controlled force piston cylinder assembly to be kept relatively small in size.

Accordingly, as illustrated in FIGURE 3, while not considered necessary in all forms of the present invention, it is advantageous to provide in the mill readily yieldable members which will allow a relatively high elastic characteristic of the elements of the mill associated with the controlled piston cylinder assembly 23. While various forms may be employed, a very simple and trouble-free arrangement includes springs located in the group of mill parts to which the controlled force is applied. In the illustrated form there is provided an opening 39 in the mill lower backup chocks 15 into which is received a spring 40, the spring having a plunger 41 with an enlarged head 42 including a spherical recess to which is received the end of the associated compression bar 34. It will be readily appreciated that there is provided in this arrangement a very simple construction to enable the modulus of the backup chock 15, bars 34, rods 31 and nuts 33 to be kept at a predetermined low value in accordance with the aforesaid objective.

To better understand the manner in which the present invention accomplishes a substantially constant roll gap condition, reference will now be made to the formula appearing in column 1 from which is derived the changing magnitude of the controlled force necessary to obtain a substantially constant gap condition. This formula is restated as follows:

$F = (Y + 1)P$ (Equation #1) in which the derivation thereof is as follows:

Let P represent the rolling load which is opposed by the controlled force developed by the piston cylinder assembly 23 and which force is designated by F . If F is always kept greater than P , then the excess load ($F - P$) will be bypassed through the bottom backup chock 15, bars 34, the screws 32 and nuts 33 and back into the housing 10. Consequently, the deflections of the mill can be divided into two separate quantities, namely, (a) the load P which is transmitted through the working rolls 19-20, backup rolls 12 and 13, and the chock of the upper backup roll, a part of the lower backup roll chock, as well as the upper portion of the housing, and (b) the load $F - P$ which is transmitted through the lower backup chock 15, bars 34, screws 32 and nuts 33. Consequently, the mill with respect to its elastic change due to varying separating forces may be looked at as constituting two separate moduli which correspond to the two groups of mill parts identified above and which can be identified as M_R = the modulus of parts transmitting the load P and M_C = the modulus of parts transmitting the load ($F - P$).

Now, in letting Y equal M_C/M_R and letting S equal the stretch or elastic change of the mill as related to a change in the roll gap, the following equation can be written:

$$S = \frac{P}{M_R} - \frac{(F-P)}{M_C} \quad (2)$$

This may be rewritten as:

$$S = \frac{YP}{M_C} - \frac{F}{M_C} + \frac{P}{M_C} \quad (3)$$

A change in the rolling condition with reference to the stretch of the mill can thus be written as:

$$\Delta S = \frac{Y\Delta P}{M_C} - \frac{\Delta F}{M_C} + \frac{\Delta P}{M_C} \quad (4)$$

Since the object in obtaining constant roll gap is to make $\Delta S=0$, this prerequisite can be established by equating Equation No. 4 to zero, thus:

$$\Delta S=0 = \frac{Y\Delta P}{M_C} - \frac{\Delta F}{M_C} + \frac{\Delta P}{M_C} \quad (5)$$

In solving for ΔF , Equation No. 5 can be rewritten as:

$$\Delta F = (Y+1)\Delta P \quad (6)$$

which can be expressed also as:

$$F - F' = (Y+1)P - P' \quad (7)$$

From this it follows that if the initial load P' is zero, then F' also is zero and, consequently, the Equation No. 1 is derived, thus:

$$F = (Y+1)P$$

It will be appreciated from Equation No. 1 that if the moduli (M_R and M_C) of the two groups of mill parts that make up Y are equal to each other, then $Y=1$ and $F=2P$. From this it follows that if M_C is proportioned so that $M_C=0.25 M_R$, then $F=1.25 P$. This points up the desirability of keeping the value of M_C sufficiently low so as to reduce the size of the screwdown 32-38 and the size of the piston cylinder assembly 23. To accomplish this it is the object of the present invention, as previously noted, to provide a built-in elastic characteristic into the elements constituting the M_C group of mill parts. In this construction springs may be provided as illustrated in FIGURE 3. By the employment of the springs, the value of M_C may be maintained low enough to obtain the necessary elastic characteristic to provide the necessary compensating ability.

With reference to FIGURE 4, which illustrates a control for practicing the invention, it should be mentioned first of all that it is the object of the control to produce a signal representing the required change in the controlled pressure according to the formula: $F=(Y+1)P$. Accordingly, in FIGURE 4 there is provided a potentiometer 46 which is manually adjusted to produce a signal representing the quantity M_R of Equation No. 2 which is sent to a summation amplifier 47, the summation amplifier 47 also receives signals from potentiometers 48 and 49 representing certain variable elastic characteristics of the roll and strip, such as, in the first case, change in size of the roll diameters and, in the second, strip width which influence the stretch of the mill. The amplifier 47 produces a modified signal representing the corrected value for the M_R quantity which is received by a dividing amplifier 51. This amplifier 51 also receives from a manually adjustable potentiometer 52 a signal representing the quantity M_C of Equation No. 2.

As indicated in FIGURE 4, the dividing amplifier 51 produces a signal representing Y which, as previously noted, equals M_C/M_R and sends the signal to a dividing amplifier 53. The dividing amplifier 53 also receives a signal from a manually operated potentiometer 54, the signal representing a value V . The signal from the amplifier 53 which is represented by a quantity Y/V is sent to an amplifier 55. This amplifier receives from a secondary

amplifier 56, a quantity $1/V$, it being noted that the amplifier 56 receives a signal representing the quantity V from the potentiometer 54. Hence, the amplifier 55 adds the values

$$\left(\frac{Y}{V} + \frac{1}{V}\right)$$

and sends a signal to a multiplying amplifier 57, which also receives a signal of the value V from the potentiometer 54. The amplifier 57, accordingly, produces a signal equaling the value $Y+1$ from the input signals representing

$$V\left(\frac{Y}{V} + \frac{1}{V}\right)$$

It should be noted that there are other ways to establish $Y+1$ and feed its signal into the system. Thus, the amplifiers 55-57 are employed to produce the quantities of Equation No. 1: $Y+1$, which signal is sent from the amplifier 57 to a summation amplifier 58. This amplifier also receives a second signal representing the rolling pressure P . As noted in the lower part of FIGURE 4, the load cell 26 sends a signal to a secondary amplifier 59 and also sends a signal to an amplifier 62 which receives a second signal from a manually operated potentiometer 63. The amplifier 62 sends its signal to a relay 64 which has a normally open contact and a normally closed contact, 64a and 64b, respectively, as shown. The potentiometer 66 produces a signal representing V_1 so that in the event that the value P is zero or below a predetermined pressure, then the signal V_1 represents the pressure of P . Relay 64 applies either the P or V_1 signal to the amplifier 59 depending on the output from the load cell. Accordingly, the amplifier 59 produces a signal; either P or V_1 and sends its signal to the amplifier 58. The amplifier 58 produces a signal normally representing $P(Y+1)$, which is sent to a solenoid 67 which operates a valve 68 that controls the pressure in the piston cylinder assembly 23 arranged at the bottom of the housing 10.

It will be appreciated that the various amplifiers illustrated in FIGURE 4 are of the typical, well-known design as exemplified in a publication by Korn and Korn, entitled "Electric Analog Computers," published by McGraw-Hill, 1952.

In operation the values of the various manual potentiometers, such as 46, 48, 49, 52, 54, 63, and 66 will be predetermined and the load cell 26 will produce a signal proportional to the actual separating force of the mill so that the pressure of the cylinder 23 which is represented by the quantity F of Equation #1 will be changed pursuant to the change in the separating force an amount necessary to compensate for any change in the effective length of the mill parts represented by the Y quantity.

Turning now to the final embodiment of the present invention, as illustrated in FIGURE 5, the arrangement illustrated differs from that of FIGURES 1 and 2 in that instead of the parallel screws, a single mill screw is provided for each housing. Accordingly, there is provided in the housing 70 openings 72 in the upper backup chocks 73 to which there is received force transmission bars 74, the bars extending between the lower backup chock 75 and the top of the housing 70, for which purpose there is provided on the housing lugs 76 which are engageable by the upper ends of the bars. The upper backup chock 73 carries a load cell 77 as do the previous mill arrangements, the upper ends of the load cell being engaged by a screw 78 which is readily received in a nut 79 non-rotatably carried by the housing 70. It will be noted that the screwdown nut 79 arrangement illustrated in FIGURE 5 is similar to present-day mill construction. Accordingly, the screw is adapted to be rotated by a worm wheel unit 80, the worm being driven by a motor, not shown.

While the aforesaid specification has illustrated a number of embodiments of the present invention, it will

be appreciated by those skilled in the art that other forms of the invention may be devised without departing from the scope thereof. It will be also appreciated that while a four-high mill has been selected to illustrate the features of the present invention, the invention may be just as readily employed in connection with other types of mills, such as two-high mills and other apparatus which require a constant roll gap, such as rubber and paper calenders.

In accordance with the provisions 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 a rolling mill for controlling the roll gap formed by working rolls thereof comprising:

a first group of related mill parts adapted to receive the separating force developed by the working rolls in processing material fed therebetween,

said first group of mill parts including the working rolls, which parts when subject to the varying separating force have a variable effective length causing a corresponding variation in the roll gap,

a second group of related mill parts which include a member not included in the first group of mill parts, said parts constructed and arranged to have a variable effective length when subject to a force,

force applicator means arranged to cause movement of one of said rolls and for applying a controlled force to both said first and second groups of mill parts,

said force applicator means exerting its force in a direction opposing said separating force and in which the algebraic sum of the forces applied to said first and second groups of mill parts is at all times greater than the separating force,

said member of said second group of mill parts being constructed and arranged to be subject only to the difference between the separating force and the controlled force, and

means responsive to a change in the separating force for controlling the force exerted by said controlled means to vary the effective length of said second group of mill parts to thereby change the roll gap in a direction to compensate for the change in length of the first group of mill parts.

2. In a rolling mill according to claim 1, including means for controlling the force applicator in accordance with the following formula: $F = (Y+1)P$ where F equals the controlled force, Y equals the proportionality of the moduli or spring coefficient of the first and second groups of mill parts and P is the separating force.

3. In a control for establishing the gap between two cooperative working rolls of an apparatus for reducing material,

said working rolls constituting a part of a first group of related mill parts adapted to receive the separating force developed by the working rolls in reducing the material,

said first group of mill parts being characterized by the fact that when subject to the varying separating force they have a variable effective length causing a corresponding variation in the roll gap,

means for producing a first signal representing the separating force developed between the rolls,

a second group of related mill parts having a variable effective length when subject to a varying force, force applicator means for developing a force of a magnitude greater than the separating force and in a direction opposing the separating force, being constructed and arranged to move at least one of the rolls of the mill to vary the gap thereof,

means for producing a second signal representative of the proportionality of the moduli of said first and second groups of mill parts,

means for receiving said first and second signal and producing a third signal representative of the change in the roll gap by reason of the changes in the effective lengths of the said two groups of mill parts which, in turn, represents the said force necessary to vary the effective length of the second group of mill parts to compensate for the change in effective length of the first group of mill parts, thereby to maintain the roll gap of the mill substantially constant, and

means for receiving said third signal and adapted to control the operation of said force applicator means.

4. In a control for establishing a gap between two cooperative working rolls according to claim 3, comprising: a fourth signal generating means adapted to produce a signal representing the modulus of the first group of mill parts,

a fifth signal generating means for producing a signal representing the modulus of the second group of mill parts,

said means for producing said second signal including means for establishing a ratio between said fourth and fifth signals, and producing said third signal, means for amplifying said third signal by a multiplier of at least one unit, and

means for multiplying said first signal representing the separating force and said third signal to produce the control signal.

5. In a control for establishing a gap between two cooperative working rolls according to claim 4, including means for generating a substitutionary signal for the first signal representing the separating force.

6. In a rolling mill according to claim 1, including means separate from the means associated with one of said rolls for setting an initial gap between the rolls.

7. In a rolling mill according to claim 1, wherein said second group of mill parts includes force transmission bars engageable with a first chock assembly of a roll on the end of the mill on which the force applicator means is located, said bars being unconnected with a secondary chock assembly of a roll on the opposite end of the mill, and engageable with said housing on that end and adapted to resist the prestressing force.

8. In a rolling mill according to claim 1, wherein said mill is a 4-high mill having windows for receiving the four roll assemblies,

said second group of mill parts including the lower backup roll chocks,

force transmission bars engageable with said lower backup roll chocks,

said bars being unconnected with the upper backup roll chocks and engageable with the upper portion of said housing, and

said means responsive to a change in the separating force being arranged between the upper backup chocks and the housings.

9. In a rolling mill according to claim 1, wherein said second group of mill parts includes a readily yieldable means, whereby said second group is characterized by a low modulus or spring coefficient as compared to the first group of mill parts.

10. In a rolling mill according to claim 7, wherein said second group of mill parts includes a readily yieldable means arranged to engage said transmission bars and to be subject to force transmitted thereby.

11. In a rolling mill according to claim 7, including four parallel screws arranged to engage a like number of transmission bars, the lower portion of said bars engaging the first chock assembly and said screws being arranged in the upper part of said mill, means for rotating said screws to displace said bars thereby changing the gap of the mill.

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12. In a rolling mill according to claim 1, wherein the moduli of said first and second group of mill parts has a predetermined relationship, said second group of mill parts being proportioned to have a substantially lower modulus than the modulus of the first group of mill parts.

13. In a rolling mill according to claim 12, wherein the modulus of said second group of mill parts is .25 of the modulus of the first group of mill parts.

14. In a rolling mill according to claim 12, including a mill housing and wherein the housing is excluded from either group of mill parts,

said force applicator means being arranged to maintain the stretch of the housing constant.

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U.S. Cl. X.R.

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