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PRESTRESSED ROLLING MILL AND CONTROL

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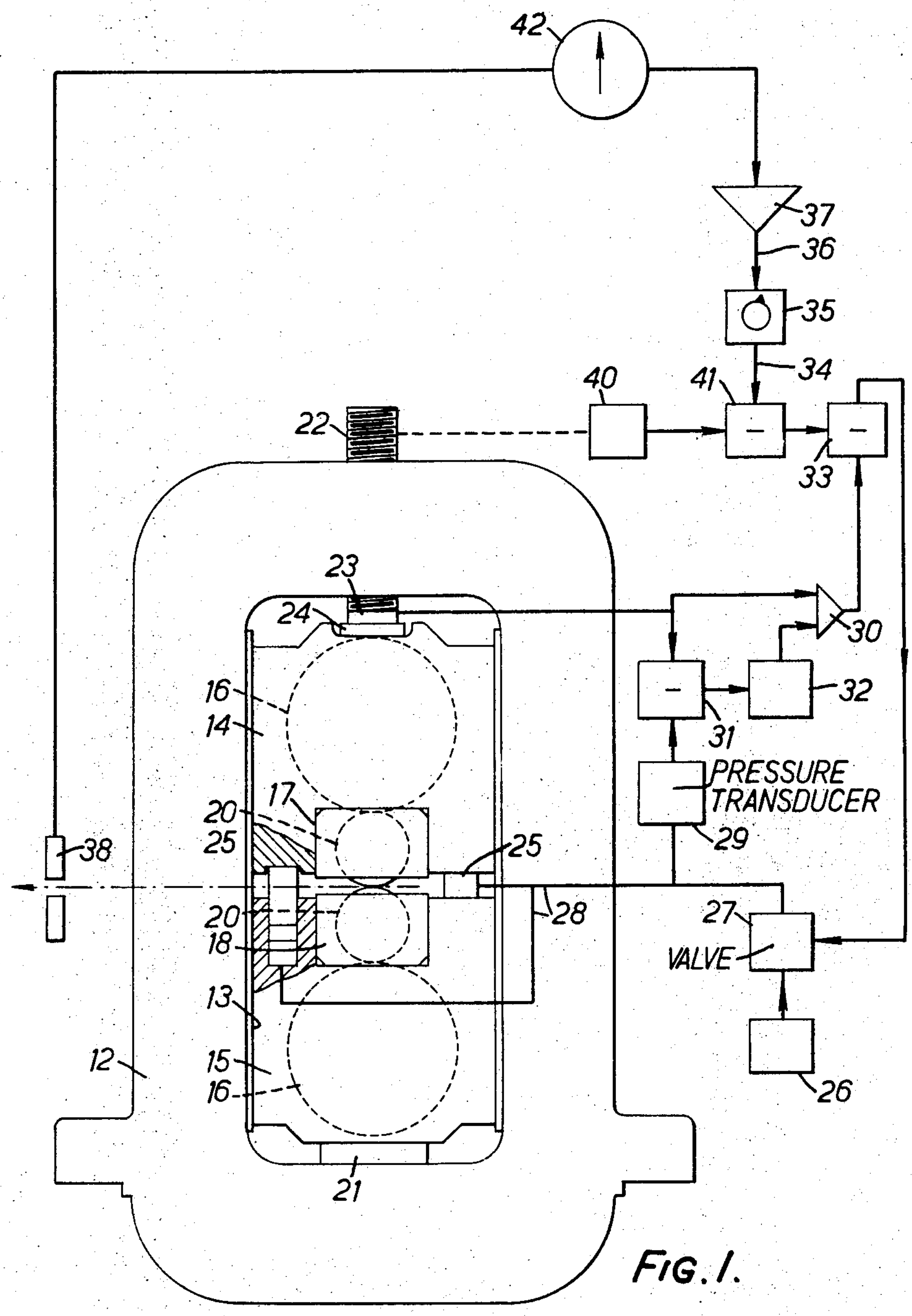

FIG. 1.

INVENTORS
ANNE KIGGELL
DENNIS STUBBS
BY
Holcombe, Wetherill & Brisebois
ATTORNEYS

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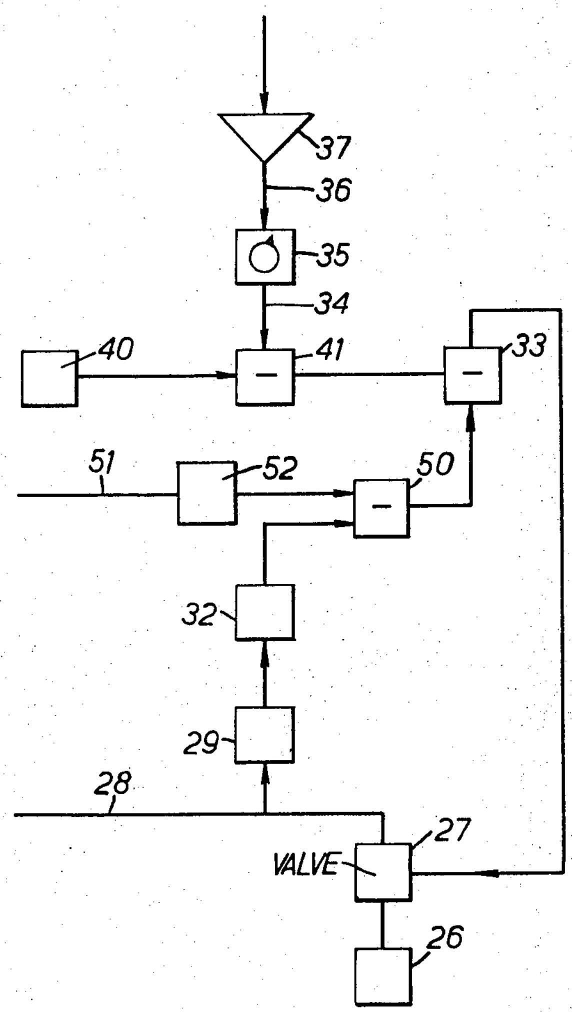

FIG. 2.

INVENTORS
ANNE KIGGELL
DENNIS STUBBS
BY
Holcombe, Wetherill & Brisebois
ATTORNEY

United States Patent Office

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PRESTRESSED ROLLING MILL AND CONTROL

Anne Kiggell, London, and Dennis Stubbs, Sheffield, England, assignors to Davy and United Engineering Company Limited, Sheffield, Yorkshire, England

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U.S. Cl. 72—8 12 Claims

ABSTRACT OF THE DISCLOSURE

The invention relates to a control scheme for a "prestressed" rolling mill, in order that the mill shall roll constant gauge. A preload is applied to the housing, but not to the rolls of the mill. The total stress in the housing due to both the preload and the rolling load is continuously measured, as is the value of the preload. From the measurements, a continuous indication is given of the variations in the roll gap due to variations in the preload and rolling load and the preload is controlled by that indication to keep the gap constant.

This invention relates to rolling mills and is more particularly concerned with control systems aimed at maintaining constant gauge of strip and other elongate material issuing from a rolling mill.

Variations in the gauge of strip leaving a rolling mill emanate from the elastic nature of the components of the mill stand; the work between the work rolls of the stand produces a separating force which elastically deforms the chocks and housing of the stand. When the separating force, or rolling load, varies, due to changes in the incoming strip, the deformation of the stand components and hence the roll gap between the working surfaces of the rolls changes, with the result that the gauge of the outgoing strip is no longer constant. To mitigate the effects of the deformation of the mill stand, it has been suggested to maintain the chocks under a preload greater than the rolling load; while prestressing in this way reduces the variations in gauge, it does not completely eradicate them.

The present invention is directed to an automatic system for compensating for variations in the deformation of stand components due to variations in the rolling load, and broadly resides in preloading those parts of the mill, the deformation of which causes changes in the roll gap, under variations of the rolling load, with the exception of the rolls themselves, measuring the load to which those parts are subjected, deriving therefrom a control signal representing variations in the roll gap due to changes in the loads to which those parts and the rolls are subjected during rolling, and controlling the preloading automatically by the control signal to maintain substantially constant the roll gap, regardless of variations of the rolling load.

Another aspect of the present invention resides in the combination of a rolling mill having two roll assemblies, between which the material to be rolled is passed and preloading means for preloading those parts of the mill, the deformation of which causes changes in the roll gap under variations of the rolling load, the preloading means applying no preload to the rolls; and control system comprising means for continuously measuring the total load to which said parts are subjected during rolling, means for deriving therefrom a control signal representing variations in the roll gap due to changes in the loads to which said parts and the rolls are subjected during rolling, and means for controlling the preloading means by the control signal to maintain substantially constant

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the roll gap, regardless of variations of the rolling load.

In a preferred form of the invention, a rolling mill comprises a mill frame, an upper and a lower roll assembly, each with a chock mounted in the frame, means disposed between the chocks of the two assemblies for preloading at least some of the chocks and the mill frame, means for generating a first signal representing the load to which the chocks and mill frame are subjected, means for generating a second signal dependent on the deformation of the rolls, and control means for controlling the preloading means automatically to maintain the sum of the first and second signals constant.

The invention will be more readily understood by way of example from the following description of a rolling mill and its control system, reference being made to the accompanying drawings, in which:

FIG. 1 schematically illustrates the mill and system, and

FIG. 2 shows a modification of the control system.

In FIG. 1, the mill stand has a pair of parallel housings, one of which is shown at **12**. Each housing has a window **13** in which an upper back-up roll chock **14** and a lower back-up roll chock **15** are slidably disposed. As usual, the necks of the back-up rolls **16** are journalled in chocks **14, 15**. The upper and lower chocks **17, 18** for the work rolls **20** are nested in recesses in the back-up roll chocks **14, 15** respectively. The lower back-up roll chock **15** is supported on a pad **21** seated on the bottom of the window **13** while a screw **22**, which can be driven by a screwdown motor not shown, engages the upper back-up roll chock **14** through a loadcell **23** and a pad **24**. In each housing, there are a pair of hydraulic rams **25** acting between the upper and lower back-up chocks **14, 15**.

As well as acting as balance cylinders, the rams **25** are employed to apply a preload force to the chocks **14, 15** and to the housing **12**, while the mill is rolling strip. For this purpose, the rams **25** of both housings are supplied from a source **26** of liquid under pressure through a pressure regulating valve **27** and the lines **28**, and the valve **27** is automatically controlled by an automatic control system. This control system employs as the detector elements the loadcell **23**, which measures the total force to which the chocks **14, 15** and the housing **12** are subjected, and a pressure transducer **29**, which is subjected to the pressure of the liquid in line **28** and which supplies an electrical signal in accordance with that pressure. The signal from loadcell **23** is applied to an adding circuit **30** and also to a differencing circuit **31**, to which the pressure signal from transducer **29** is also applied. The difference signal from circuit **31** is applied through a modifying circuit **32** to the adding circuit **30**. The output from circuit **30** is applied to a comparing circuit **33**.

A reference signal on line **34** is obtained from a reference generator **35**, which can be adjusted by hand and which is also adjusted automatically by the output on line **36** from an integrating circuit **37**. Circuit **37** has applied to it the output from a direct acting thickness gauge **38**, which output is proportional to the difference between the detected gauge of the outgoing strip and the required gauge.

The screws **22** are coupled to a potentiometer or other transducer **40** which gives a signal representing the mean position of the screws. This signal and the signal on line **34** are differenced in the subtracting circuit **41**, the difference signal being applied to the circuit **33** in which it is compared with the signal from adding circuit **30**. The difference signal from circuit **33** is applied to the pressure regulating valve **27**.

In operation, before rolling commences, a predetermined pressure is applied to the rams **25**; this pressure produces a preload which exceeds possible variations in rolling load. Thereafter, the screws **22** are adjusted to give a roll gap approximating that required for the desired gauge. In each housing, therefore, the back-up roll chocks **14, 15** and the frame **15** are subject to a preload P, which tends to lengthen the housing **12** and compress the chocks **14, 15**. None of the rolls **16, 20** are subjected to this preload, where the work rolls **20** are not in contact prior to entry of the work.

When rolling commences, the preload is augmented by the rolling load W, so that the housing **12** and the chocks **14, 15** are now subject to forces $P+W$; however, the rolls **16, 20** are subject only to the rolling load W.

The initial roll gap S, i.e., the separation of the working surfaces of the work rolls **20** when the preload P and the rolling load W are zero, is set by the screws **22** and measured by the potentiometer **40**. The roll gap increases when the hydraulic pressure is applied to the rams **25** to

$$S+P/M_f$$

where M_f is the spring modulus of the housings and chocks and to

$$S+(P+W)/M_f+W/M_r$$

on the commencement of rolling, where M_r is a function of the roll parameters, permitting the calculation of an equivalent roll distortion which for illustrative purposes may be considered as a simple spring modulus. This expression represents the thickness of the material rolled and the control system operates to maintain constant the function $(P+W)/M_f+W/M_r$, regardless of variations in the rolling load W, and thus maintains constant thickness of rolled material.

The loadcell **23** is subject to the sum of the preload and rolling load $(P+W)$ and its electrical output is proportional to this sum. On the other hand, pressure transducer **29** has an output proportional to the preload P so that the differencing circuit **31** gives an output proportional to the rolling load W, only. The signal W from circuit **31** is multiplied in the modifying circuit **32** by a corrective function considered for illustrative purposes to be a simple constant of proportionality K. The modifying circuit **32**, which may be a potentiometer or like device, may be adjusted to give varying values of K, by hand or automatically or may be a non-linear function generator.

The sum output from adding circuit **30** is then the sum of the signals from loadcell **23** and the modifying circuit **32**, i.e.

$$(P+W)+KW$$

The modifying circuit **32** is set to give a value K equal to M_f/M_r, so that the output from circuit **30** now represents the enlargement of the roll gap due to the preload and rolling load.

The generator **35** is set by hand to the required gauge (h'), so that the differencing circuit **41** applies the reference signal $(h'-S)$ to the comparing circuit **33**. The value for the enlargement of the roll gap is maintained constant by comparing it with this reference signal in the comparing circuit **33** and employing the error signal to control the preload P, by means of the pressure regulating valve **27**. In this way, the roll gap is kept constant, regardless of variations in rolling load, due to variations in the characteristics of the strip entering the mill and as a result, the gauge of the outgoing strip is held substantially constant. Furthermore, changes in gauge can be made by manual adjustment of generator **35**, while any adjustment of the screws **22** is automatically introduced by the potentiometer **40**.

As before mentioned, the thickness gauge **38** gives an output representing the departure of the outgoing strip thickness from the required value (h') and this departure is indicated on a meter **42** and applied to the integrating circuit **37**. If the control circuit before described operates entirely satisfactorily, the thickness gauge **38** will of course have zero output. If, however, there should be a

residual gauge error, there will be a signal from the gauge **38**, the time integral of which will be produced on line **36** to modify the reference signal supplied by generator **35** and thus cause the roll gap to be maintained constant at a value, differing from that previously held but more suitable for the required output gauge.

FIG. 2 illustrates a modification of the control system of FIG. 1, like elements in both figures being given the same reference numerals. The expression for the roll gap and the rolled thickness:

$$S+(P+W)/M_f+W/M_r$$

can be written

$$S+(P+W)\left(\frac{1}{M_f}+\frac{1}{M_r}\right)-P/M_r$$

or

$$S+(P+W)/M-P/M_r$$

where M is the spring modulus of the mill.

The gauge error is then

$$(S-h')+(P+W)/M-P/M_r$$

In FIG. 2, the signal from pressure transducer **29** is applied to modifying circuit **32** which introduces the factor $1/M_r$. The modified signal is now applied to differencing circuit **50**, to which is also applied the signal on line **51** from loadcells **23** via a modifying circuit **52** which introduces the factor $1/M$. The difference signal proportion to

$$(P+W)/M-P/M_r$$

is fed to comparing circuit **33**, to produce the gauge error signal which controls valve **27**, as before.

Although, in the mill illustrated and described, the preload is applied between the two roll assemblies on opposite sides of the pass line, it will be appreciated that the invention may be applied equally to other forms of prestressed mill, such as that in which there are adjustable spacers between the two roll assemblies and the preload is applied at the location of the pad **21** to force the roll assemblies towards one naother. In this case, the loadcell **23** is located in the spacers, so as to give an output signal representing the difference between the preload force and the rolling load. In this case, the thickness of the rolled material, which equals the roll gap modified by the compression of the spacers and the deformation of the rolls, is

$$S+F/M_r-(P-F)/M_s$$

where M_s is the spring modulus of the spacers and M_r is the spring modulus of the rolls, as before. $(P-F)$ is given by the signal from the loadcells in the spacers and F is given by the output of the differencing circuit **31** (FIG. 1). The output of adding circuit **30** thus gives, as before, the deformation of the roll gap due to the preload force and the rolling load. Where the spacers are adjustable, as when they are screws, the initial roll gap value S may be introduced by connecting the potentiometer **40** to those screws.

Where roll cambering equipment is supplied to provide controlled camber of the rolls for shape correction, the camber control equipment may be automatically controlled by the signal from the differencing circuit **31**, since roll bending arises from, and is dependent on, the rolling load. Dependent on the manner in which the camber control is applied, this may demand a complete revision of the control equations above, and hence the detailed control equipment.

What is claimed is:

1. A method of automatically controlling a rolling mill to maintain substantially constant the thickness of rolled material comprising preloading parts of the mill, the deformation of which causes changes in the roll gap under variations in the rolling load, said parts not including the rolls, continuously measuring the total load to which those parts are subjected due to the rolling load and the preload, continuously measuring the value of the preload, deriving a control signal representing variations in the roll gap due to changes in said total load and said preload, and controlling the preloading automatically by said control signal to maintain substantially constant the roll gap, regardless of variations of the rolling load.

2. A method according to claim **1** in which a first signal is obtained representing said total load to which said parts are subjected, a second signal is derived from said total load and said preload representing the rolling load, and said first and second signals are combined together to obtain said control signal.

3. A method according to claim **1** in which a first signal is obtained representing said total load to which said parts are subjected, a second signal is obtained representing said preload, and first and second signals are combined together to obtain said control signal.

4. The combination of a rolling mill having two roll assemblies, between which the material to be rolled is passed and preloading means for preloading those parts of the mill, the deformation of which causes changes in the roll gap under variations of the rolling load, the preloading means applying no preload to the rolls; and a control system comprising means for continuously measuring the total load to which said parts are subjected during rolling, means for measuring the value of said preload, means for deriving a control signal representing variations in the roll gap due to changes in said preload and rolling load, and means for controlling the preloading means by the control signal to maintain substantially constant the roll gap, regardless of variations of the rolling load.

5. The combination according to claim **4** in which the measuring means are arranged to generate a first signal representing the total load to which said parts are subjected, and in which there are means for generating from said measuring means for said total load and said preload a second signal representing the rolling load, and means for combining those signals together to derive the control signal.

6. The combination according to claim **5** in which the means for generating the second signal comprises a detector for detecting the preload and means for differencing the first signal and the preload.

7. The combination according to claim **4** in which the measuring means are arranged to generate a first signal representing the total load to which said parts are subjected, and in which there are additionally a detector for generating a second signal representing the preload, and means for combining the first and second signals together to derive the control signal.

8. The combination according to claim **7** in which the preloading means are hydraulic rams between the roll assemblies, said detector being arranged to detect

the pressure of the hydraulic supply to the rams, and the controlling means are pressure control means for the rams.

9. The combination according to claim **4** in which there are means for generating a reference signal, presenting the predetermined roll gap deformation, means for differencing the first and second signals to obtain a difference signal, and means for comparing the difference signal with the reference signal to obtain the control signal.

10. The combination according to claim **9** in which the reference signal is derived in part from means for indicating the undeformed roll gap.

11. The combination according to claim **9** in which there is a direct acting thickness gauge for measuring the thickness of the rolled material leaving the mill and for giving a signal representing the gauge error, and means for applying the gauge error signal to the reference signal generating means to change the reference signal until the gauge error is substantially zero.

12. In a rolling mill, having a plurality of rolls rotatively mounted about substantially parallel axes, bearing means for supporting the rolls, means supporting the bearing means for constraining the separating forces imparted to the rolls by the product being rolled, means mounted on the supporting means and acting on at least one roll to set the separation between the rolls, adjustable actuator means acting on the supporting means directly through the bearing means to apply a force which coacts with a separating force to oppose the force constrained by the supporting means, means to derive a control signal from the force constrained by the supporting means and the force applied by the adjustable actuator means, and actuator varying means responsive to the control signal to vary the force applied by the adjustable actuator means to maintain the work roll separation.

References Cited

UNITED STATES PATENTS

2,903,926	9/1959	Reichl	72—8
3,159,063	12/1964	Fox	72—21
3,247,697	4/1966	Cozzo	72—240
3,285,049	11/1966	Neumann	72—246
3,327,508	6/1967	Brown	72—6
3,315,507	4/1967	Marten	72—16

FOREIGN PATENTS

955,164 4/1964 Great Britain.

MILTON S. MEHR, Primary Examiner

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