United States Patent [19]

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[11] **3,803,887**

[45] **Apr. 16, 1974**

[54] **CONTROL DEVICE FOR ROLLING MILLS**

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[22] Filed: **Mar. 2, 1972**

[21] Appl. No.: **231,147**

Related U.S. Application Data

[63] Continuation of Ser. No. 832,952, June 13, 1969, abandoned.

[52] **U.S. Cl.** **72/11**

[51] **Int. Cl.** **B21b 37/00**

[58] **Field of Search** 72/8–12, 16

[56] **References Cited**

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[57] **ABSTRACT**

A control device for rolling mills adapted to control the roll gap opening S to obtain a required thickness h of a rolled material according to a relation S = h–P/M, wherein P is the rolling pressure and M is the spring constant of the roller stand, characterized in that the value of M is intermittently computed and renewed in a rolling process according to the results of intermittent measurements of a set of values of the roll gap, thickness of the rolled material and rolling pressure relating to each determined portion of the rolled material.

13 Claims, 3 Drawing Figures

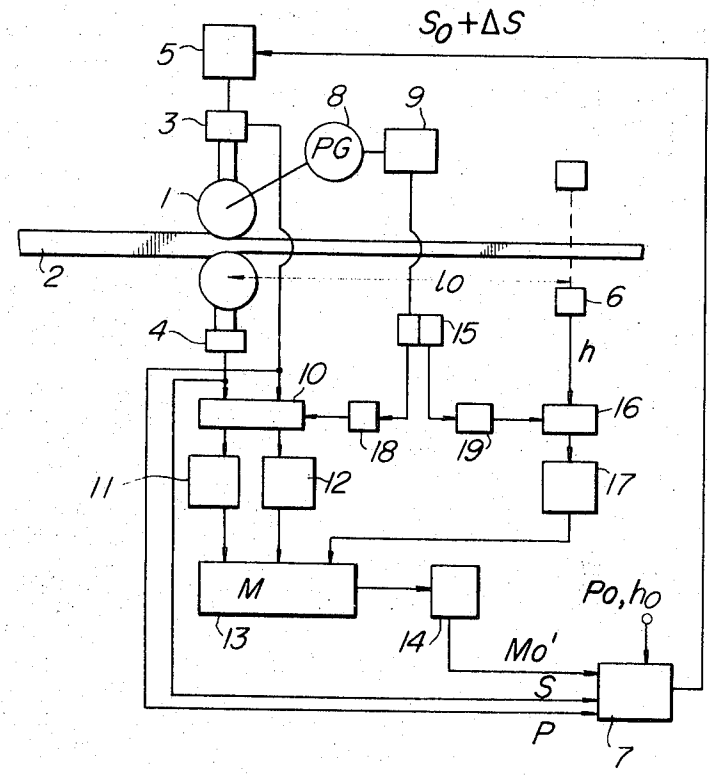


FIG. 1
PRIOR ART

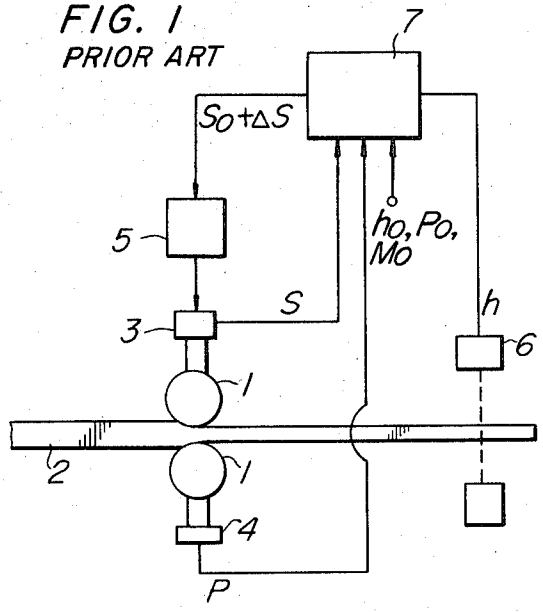
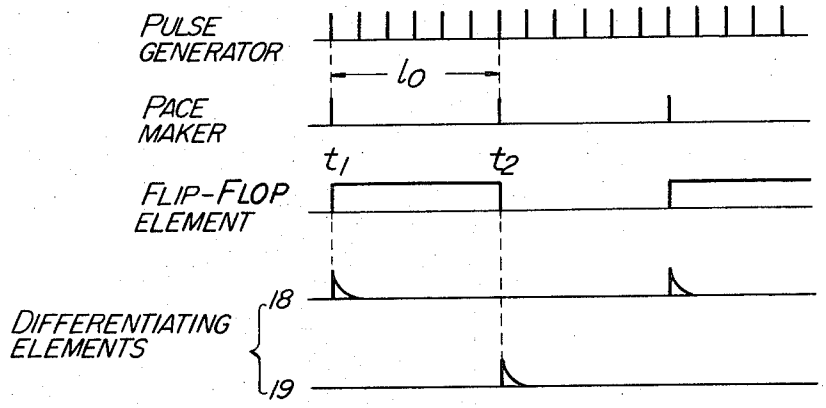


FIG. 3



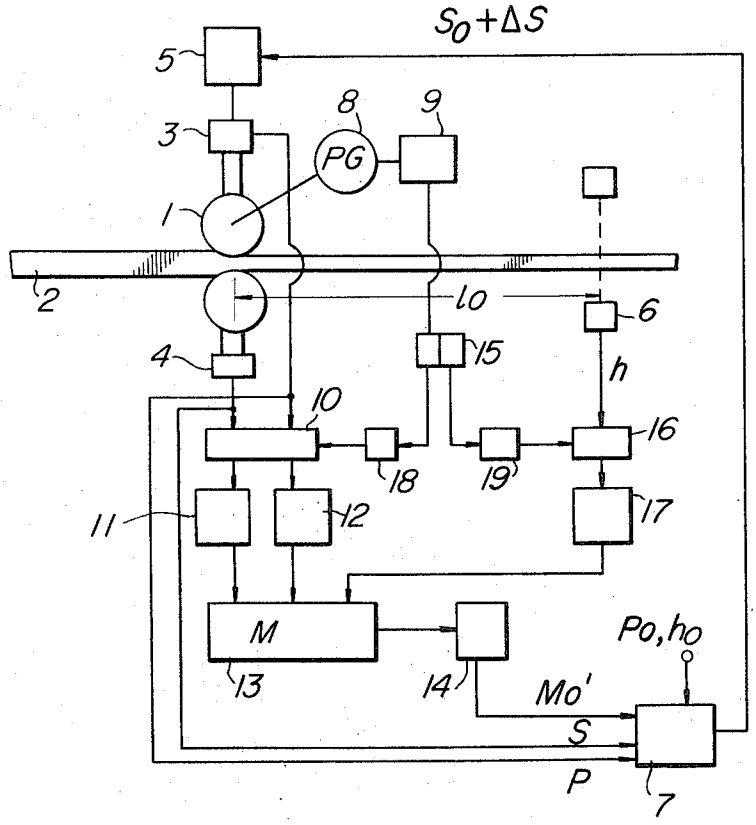
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FIG. 2



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CONTROL DEVICE FOR ROLLING MILLS

This is a continuation application of Ser. No. 832,952, filed June 13, 1969, now abandoned.

This invention relates to a control device for rolling mills, and more particularly a control device for rolling mills adapted to control a roll gap based upon values of the spring constant of the roller stand.

Generally in hot rolling, a control device for rolling mills is so adapted as to modify a set value of the roll gap based upon the measurement of the rolling pressure P since there is a relation among the rolling pressure P, the roll gap S and the thickness h of a rolled material according to a formula

$$h = S + P/M \quad \ldots . \quad (1)$$

wherein M represents the spring constant of the roller stand. In the past, the modification of the gap S has been performed based upon the data obtained at the time when the leading end portion of a material to be rolled has just been nipped between the rollers. Therefore, if the spring constant of the roller stand has not been correctly adjusted during rolling process, there occurs an error in the roll gap, so that an accurate control of the thickness of rolled materials over the whole length thereof cannot be attained.

A conventional control device for rolling mills is shown in FIG. 1, wherein reference numeral 1 designates a pair of cooperating rollers of a rolling mill, between which is passed a material 2 to be rolled. A roll gap between the rollers 1 is controlled by a roll gap controller 3, while the rolling pressure exerted on the rollers is measured by a rolling pressure detector 4. Reference numeral 6 designates an X-ray thickness gauge which is adapted to measure the thickness of the rolled material. Reference numeral 7 designates an operation unit for producing a control signal which is fed to the gap controller 3 via a memory element 5.

In the operation of this conventional control device, at first the roll gap S_o and spring constant M_o are tentatively preset. When the leading end portion of a material has just been rolled, measurements are performed on the rolling pressure P_o, and the rolled thickness h_o can be calculated by the following equation:

$$h_o = S_o + P_o/M_o \quad \ldots . \quad (2)$$

The rolling operation is carried out by making the calculated rolled thickness h_o as a target value. Namely, when the temperature and characteristics of the material to be rolled, such as hardness or plasticity, gradually change, the influence thereof is detected by the rolling pressure detector 4, and errors produced between the thickness h calculated by using Formula (1) as a function of the rolling pressure P actually measured by the detector 4 and the target value h_o, and the roll gap is controlled continuously or at a suitable sampling time to make these errors zero. Further, the target thickness h_o in Formula (2) is corrected by the result of the actual thickness of the rolled material measured by the thickness gauge 6.

As will be thus apparent in this conventional controlling method, the value of the spring constant M has been assumed to remain constant throughout the rolling process, while the value of the spring constant actu-

ally changes during the rolling operation due to the temperatures of the rollers and material being rolled and many other factors and changes in the spring constant produced during the rolling process are not compensated. Therefore, in this point of view, there has been a limit of the accuracy in the conventional method of controlling the thickness of a rolled material. When the correction of the target thickness h_o is made by using the value measured by the thickness gauge 6, the correction includes a compensation of a change ΔM of the spring constant, but this is only made at the beginning of the rolling process and, therefore, the changes of the spring constant produced during the subsequent rolling process are not compensated at all.

This problem will be explained in more detail. As described in the above, the controlling operation of the conventional control device is based upon the spring constant M_o which is assumed invariable. However, if the spring constant were to change from M_o to M during the rolling process, the rolling pressure P_o would be assumed to change to P, so that the roll gap should be calculated according to the following equation:

$$S = h_o - P/M \quad \ldots . \quad (3)$$

Nevertheless, in the conventional feed-back control (AGC) of the roll gap, wherein the control is carried out by detecting the rolling pressure continuously or at a suitable sampling period, the roll gap is in fact controlled to be $(h_o - P/M_o)$, and therefore, the error in the roll gap will be:

$$S = (h_o - P/M_o) - (h_0 - P/M) = (1/M - 1/M_o)P$$

and this error leads to an error of the rolled thickness Δh.

To avoid the above-mentioned error in the rolled thickness, it is conventional to calculate the error Δh from the target thickness h_o and the actually measured thickness h and then to modify the roll gap by an amount ΔS corresponding to Δh. However, in order to accurately calculate the amount of correction ΔS which will compensate the error Δh, the amount ΔS must be computed by the relationship $S = h - P/M$. Therefore, if the value of the spring constant M would not be duly appreciated, the amount ΔS would inevitably include a secondary error. In fact, since the value of the spring constant is assumed to be M_o, the roll gap will tend to be overcontrolled beyond a target value. To avoid such overcontrolling, compensation of the error Δh has been generally restricted within, for example, about 80 percent, rather than 100 percent. This fact naturally lowers the accuracy of control.

Accordingly, a main object of this invention is to provide a control device for rolling mills wherein the control of the roller gap is accurately performed based upon a value of the spring constant calculated from values of roll gap, rolling pressure and thickness of the rolled material measured at a specified portion of the rolled material.

Another object of this invention is to provide a device for determining the value of the spring constant during the rolling process of a rolling mill.

Still another object of this invention is to provide a device for obtaining data such as variations in the roll gap, rolling pressure and thickness of a rolled material

relating to any specified portion of the rolled material in a rolling process.

According to this invention, the main object of this invention is accomplished by a control device for rolling mills having a roller stand including at least a pair of rollers, comprising means for presetting the spring constant of the roller stand, means for measuring the rolling pressure at the rollers, means for indicating and controlling the roll gap, and means for measuring the thickness of a rolled material, the feedback control of the roll gap being made based upon the spring constant preset by said spring constant presetting means, the thickness of the rolled material measured by said thickness measuring means, and the rolling pressure measured by said rolling pressure measuring means, characterized in that the present value of the spring constant is corrected during rolling process by a value of the spring constant calculated from values of a roll gap, rolling pressure and thickness of the rolled material measured at a specified portion of the rolled material.

In the accompanying drawings,

FIG. 1 is a diagrammatic illustration of a conventional control device for rolling mills for aiding an understanding of the description of the prior art;

FIG. 2 is a diagrammatic illustration of an embodiment of the control device for rolling mills according to this invention; and

FIG. 3 is a diagram showing the operations of some parts of the device shown in FIG. 2.

In FIG. 2, it is to be understood that the elements designated by the same reference numerals as those in FIG. 1 are the same elements as those in FIG. 1. Reference numeral 8 designates a tachogenerator or a pulse generator which is drivingly connected with the roller 1 and generates an output such as a voltage or a series of pulses in proportion to the rotational speed of the roller 1. The output of the tachogenerator or the pulse generator is introduced into a pacemaker 9 which is adapted to integrate the output voltage or pulses to emit a series of pulses indicating periodically the time T required for any specified portion of a rolled material to traverse the distance l_o from the rolling point to a point where the thickness of the rolled material is measured by the thickness gauge 6.

The output of the roll gap controller 3, indicating the roll gap S, is introduced into a memory 12 via a gate 10. In the same manner, the output of the rolling pressure detector 4 indicating the rolling pressure P is introduced into a memory 11 via the gate 10. The data stored in the memories 11 and 12 are used in an operation unit 13 which calculates values of the spring constant M of the roller stand, and the calculated values are stored in a memory 14. On the other hand, the output of the pacemaker 9 is introduced into a flip-flop circuit 15 which generates trigger pulses for opening the gate 10 or a gate 16 alternatively. The gate 16 is adapted to control the supply of data of the rolled thickness from the thickness gauge 6 to a memory 17. Reference numerals 18 and 19 represent differentiation circuits.

In operation, when a work piece material 2 is being rolled through the rollers 1, the rolling speed of the rolled material is detected by the tachogenerator or pulse generator 8, and whenever the pacemaker 9 has integrated a predetermined value of a predetermined number of pulses, it actuates the flip-flop circuit 15 to momentarily open the gate 10 or 16. In this case, the pacemaker 9 is so adjusted as to actuate the flip-flop circuit 15 to momentarily open the gate 16, when a portion of the rolled material which had been rolled at the moment when the gate 10 was opened by the flip-flop circuit has just traversed the distance l_o. Accordingly, the memories 11, 12 and 17 can store a set of rolling data of the rolling pressure P, roll gap S and thickness h for the same portion of the rolled material.

The above-mentioned operation of the control device is shown as a diagram in FIG. 3. The pulse generator 8 generates a series of pulses in succession according to the rotation of the roller 1. The pacemaker 9 integrates these pulses and every time when it has integrated a predetermined number of pulses which correspond to the traversing of a length of the rolled material for the distance l_o extending from the rolling point to the thickness measuring point, it produces a signal for switching the flip-flop circuit 15. The positive signal of the output of the flip-flop circuit is differentiated by the differentiation circuit 18, whereby a momentary signal for opening the gate 10 is obtained. On the other hand, the negative signal of the output of the flip-flop circuit is differentiated by the circuit 19 in a negative sense, whereby a momentary signal for opening the gate 16 is obtained. When the gate 10 is opened by the above-mentioned signal from the circuit 18, the memories 11 and 12 are charged with data of the rolling pressure P and the roll gap S at that instant, respectively. Then, after a lapse of time when the portion of the rolled material in which the pressure P and the gap S have been just measured reaches the thickness gauge 6, the gate 16 is opened by the signal from the circuit 19, whereby the memory 17 is charged with a value of the thickness h of the same portion.

Now, the memories 11, 12 and 17 have been charged with the measured data of rolling pressure P', measured data of roll gap S' and the data of rolled thickness h' as measured on the same portion of the rolled material in which P' and S' have been measured, respectively. The operation unit 13 is operated to calculate an actual value of the spring constant Mo' from the actually measured values P', S' and h' according to Formula 1, and the value Mo' is stored in a memory 14. Then, the computer 7 computes an amount of correction of the roll gap based upon the roll gap S, the rolling pressure P and the actual spring constant M_o' stored in the memory element 14. The computed amount of correction of the roll gap is introduced into the roll gap controller 3 via the memory 5.

Thus, according to this invention, the control of the roll gap is always performed based upon the latest value of the spring constant of the roller stand, and therefore, the amount of correction ΔS obtained in this invention does not include such a secondary error as included in case of the prior art. Therefore, it will be understood that the accuracy of control is very much improved. The correction ΔS is obtained from the following equations:

$$S_o = h_o - P_o/M_o \ldots . \quad \text{(from equation 2)}$$

$$S_o' = h_o - P_o/M_o' \ldots . \quad (4)$$

$$\Delta S = S_o - S_o' \ldots . \quad (5)$$

$$p1\ \Delta S = S_o + (P_o/M_o' - h_o) \ldots . \quad (6)$$

The correction of values of the required roll gap based upon the latest value of the spring constant may be performed every time the work piece advances one pace of the pacemaker or once in several paces according to the predetermined accuracy. When the fluctuation of thickness of a rolled material is small, such a portion of the rolled material that is to be subjected to the thickness measurement may be considered in the sense of a relatively wide extent of the material.

What I claim is:

1. A control device for rolling mills having a roller stand including at least a pair of rollers, comprising means for presetting the spring constant of the roller stand, means for measuring the rolling pressure at the rollers, means for indicating and controlling the roll gap, and means for measuring the thickness of a rolled material, a feedback control of the roll gap being made based upon the spring constant preset by said spring constant presetting means, the thickness of the rolled material measured by said thickness measuring means, and the rolling pressure measured by said rolling pressure measuring means, characterized in that the present value of the spring constant is corrected during rolling process by a value of the spring constant calculated from values of a roll gap, rolling pressure and thickness of the rolled material measured at a specified portion of the rolled material.

2. A control device according to claim **1,** wherein the values of the roll gap and rolling pressure are intermittently stored in memories through a first gate and the value of the thickness of the rolled material is also intermittently stored in another memory through a second gate, said second gate being opened after said first gate with a time lag during which a portion of the rolled material moves from the rolling point to a point of thickness measurement.

3. A control device according to claim **2,** wherein said first and second gates are controlled by a flip-flop circuit which in turn is actuated by a pacemaker which produces a control signal for every determined rotation of the rollers.

4. A control device according to claim **3,** wherein said pacemaker is an integrator of electric power output of a tachogenerator driven by the roller.

5. A control device according to claim **3,** wherein said pacemaker is an integrator of a series of pulses generated by a pulse generator driven by the roller.

6. A control device according to claim **3,** wherein said first and second gates are controlled by said flip-flop circuit through differentiating circuits.

7. A control device according to claim **2,** wherein the computed value of the spring constant is stored in a memory.

8. A control device according to claim **7,** wherein the roll gap is controlled based upon the target thickness of the rolled material, present values of the rolling pressure and the value of the spring constant stored in said memory.

9. In a rolling mill apparatus having a roll stand including at least a pair of rollers, means for measuring the rolling pressure between said rollers, means for controlling the roll gap between the rollers in accordance with a spring constant of the roll stand and means for measuring the thickness of rolled material, the improvement comprising:

means responsive to the parameters of rolling pressure and thickness of rolled material during the rolling of material by said rollers for correcting the preset value of the spring constant of said roll stand prior to further rolling of material in response to changes in said parameters.

10. An apparatus according to claim **9,** wherein said correcting means includes means responsive to the movement of material between said rollers for intermittently updating the preset value of the spring constant of the roll stand.

11. An apparatus according to claim **10,** wherein said updating means includes a pulse generator for generating a series of pulses in dependence upon the rotation of said rollers, means connected to said pulse generator for generating a count signal indicative of a predetermined number of pulses and a flip-flop circuit responsive to said count signal generating circuit for enabling said parameters to be supplied to said correcting means.

12. An apparatus according to claim **11,** further including first and second gate circuits respectively connected to receive the outputs of said rolling pressure measuring means, roll gap controlling means and said thickness measuring means, and first and second differentiating circuits, responsive to the respective binary outputs of said flip-flop for causing the opening of said first and second gate circuits, the outputs of said gate circuits being stored within memory circuits provided in said correcting means.

13. An apparatus according to claim **12,** further including a parameter computing circuit for determining the value of said spring constant from the parameters stored in said memory circuits and for registering said spring constant in a memory to be supplied to an updating computer for correcting said spring constant preset value.

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