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ROLLING MILL CONTROL SYSTEM

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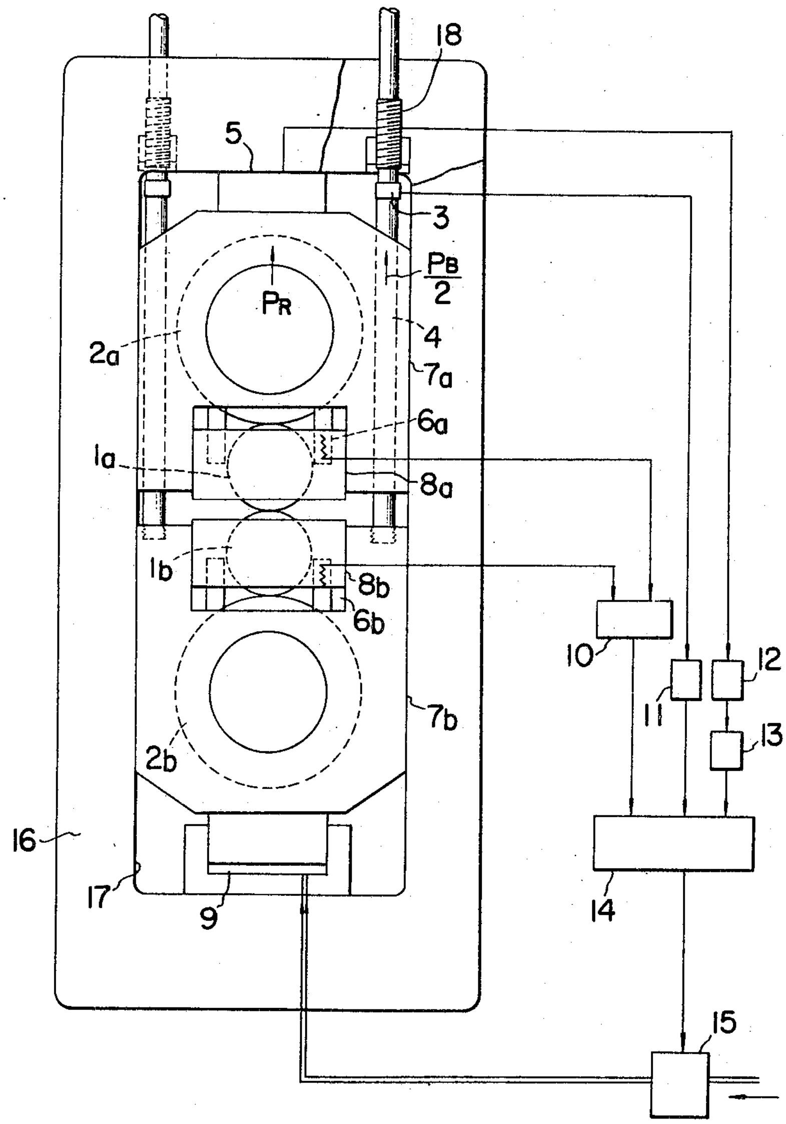

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ROLLING MILL CONTROL SYSTEM

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ABSTRACT OF THE DISCLOSURE

In a four-high rolling mill, an electrical signal representing the rolling load, an electrical signal representing the force exerted by mill screws, and an electrical signal representing the distance between axes of working and back-up rolls are compared to control a hydraulic cylinder acting upon one of the back-up roll bearing clocks so as to maintain constant gauge.

BACKGROUND OF THE INVENTION

This invention relates to rolling mill control systems and more particularly to an apparatus for eliminating effects caused by displacement of rolls of rolling mills whereby to prevent variations in the gauge of the plates or sheets due to displacement of the rolls.

It is well known in the art that displacements of back-up rolls of a rolling mill whose roll gap is maintained at a constant value by hydraulic pressure are reflected in the longitudinal gauge of the products reduced by the rolling mill so that it is difficult to obtain products having constant gauge.

Accordingly, it is an object of this invention to provide an effective control system capable of eliminating the effect on the gauge of the plates caused by the displacement of back-up rolls or at least a portion of the effects caused by the variation in the diameter of the roll or at least a portion of the effect caused by the displacement of the axes of rotation of the back-up or working rolls due to variations in the thickness of the bearing oil film caused by the variations in the load or speed of the rolls.

In accordance with this invention, there is provided a novel control system for a rolling mill including a pair of working rolls, a pair of back-up rolls, mill screws for adjusting the position of said back-up rolls, said control system comprising a hydraulic cylinder associated with one of said back-up rolls, a first load cell associated with at least one of said mill screws for generating an electrical signal representing the force exerted thereby, a second load cell associated with the other of said back-up rolls to provide an electrical signal representing the rolling load, means associated with said working and back-up rolls for generating an electrical signal representing the distance between the axes of said working and back-up rolls and means to compare said electrical signals to control said hydraulic cylinder.

BRIEF DESCRIPTION OF THE DRAWING

This invention can be more fully understood from the following description taken in connection with the accompanying drawing in which a single figure illustrates one embodiment of this invention, partly in schematic side elevation and partly in block diagram.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the accompanying drawing, a four-high rolling mill shown therein comprises a pair of housings **16** (only one of which is shown) each including a rectangular vertical window **17**. A pair of working rolls **1***a*

and **1***b* and a pair of back-up rolls **2***a* and **2***b* are disposed between housings and opposite ends of these working rolls, and the back-up rolls are respectively supported by working roll bearing chocks **8***a* and **8***b* and back-up roll bearing chocks **7***a* and **7***b*. The working roll bearing chocks are slidably received in recesses in back-up roll bearing chocks **7***a* and **7***b* which are slidably received in windows **17** of housings **16** in a manner well known in the art. A pair of adjusting rods **4** are secured to or urged against the upper surface of the lower back-up roll bearing chock **7***b* and freely pass through upper back-up roll bearing chock **7***a*. A load cell **3** is interposed between the upper end of each adjusting rod and screw **18** of the mill to measure force P_B applied to the adjusting rod. Another load cell **5** is interposed between the upper surface of the upper back-up roll bearing chock **7***a* and an upper yoke of the housing to measure force P_R or rolling load on the back-up roll. Devices **6***a* and **6***b*, such as differential transformers, potentiometers and the like are interposed between cooperating pairs of back-up and working roll bearing chocks **7***a*, **8***a* and **7***b*, **8***b* to measure variations in the spacing therebetween to generate electrical signals representing said variations. As shown in the drawing the lower back-up roll bearing chock **7***b* is urged upwardly by a hydraulic cylinder **9** interposed between the bottom thereof and the bottom yoke of the housing. Electric signals from measuring devices **6***a* and **6***b* are added by an adder **10** to provide a signal representing the deviation of the sum from a reference signal. As the outputs from load cells **3** and **5** are comparatively smaller than those from measuring devices **6***a* and **6***b*, they are amplified by amplifiers **11** and **12**, respectively, and the cutput *e*R from amplifier **12** is further converted into a proportional output Ce_R by a multiplier **13**. A comparator **14** which may include an amplifier is provided to compare the output signal from adder **10** with the out signals from amplifier **11** and multiplier **13** to provide an output signal to control a pressure regulator **15** for the fluid pressure supplied to the hydraulic cylinder **9**.

In the above arrangement, if S_I represents the roll gap, P_R the rolling load, S_o the roll gap when load P_B on both adjusting rods **4** is zero, K_R the spring constant of the roll system, and K_B the spring constant of adjusting rods **4**, the following equation can be obtained.

$$S_I - S_o = \frac{P_R}{K_R} - \frac{P_B}{K_B} \qquad (1)$$

Further, if it is assumed that the ratio between P_R and P_B is maintained at a constant value and the $1/C$ represents the proportional constant, then

$$S_I - S_o = \frac{P_R}{K_R} - \frac{CP_R}{K_B} = \left(\frac{1}{K_R} - \frac{C}{K_B}\right) P_R \qquad (2)$$

By putting

$$C = \frac{K_B}{K_R}$$

the left hand side of Equation 2 becomes zero which means that the roll gap is independent of the rolling load.

On the other hand, if

$$C < \frac{K_B}{K_R}$$

then the left hand side of Equation 2 will have a definite value. Displacement of one or both of back-up rolls 2*a* and 2*b* causes a result equivalent to the variation in roll gap S_o, thus causing the plate gauge to vary.

The comparator **14** functions to establish a relation

$$\frac{P_R}{P_B} = \frac{1}{C}$$

or

$$CP_R - P_B = 0 \quad (3)$$

By introduction into Equation 3 a quantity proportional to the sum S_e of two signals representing displacements of back-up rolls **2***a* and **2***b* measured by measuring devices **6***a* and **6***b*, we obtain

$$CP_R - P_B - K_B S_e = 0 \quad (4)$$

When Equation 4 is substituted in Equation 1, the following equation representing the control for the operation wherein rolls are displaced can be obtained.

$$S_I - (S_o - S_e) = \frac{P_R}{K_R} - \frac{CP_R - K_B S_e}{K_B} = \left(\frac{1}{K_R} - \frac{C}{K_B}\right) P_R + S_e \quad (5)$$

Since signal S_e representing roll displacement is included in both the left and right hand sides of Equation 5, it is clear than Equation 5 is equivalent to Equation 2.

Thus the effects of roll displacements are eliminated, so that the relation between roll gap and rolling load as expressed by Equation 2 can be always maintained irrespective of the presence or absence of roll displacement.

Adder **10** supplies an electric signal $e_E = \epsilon K_B S_e$ which represents the roll deflection. Since electric signals produced by load cells **3** and **5** are substantially smaller than signals produced by measuring devices **6***a* and **6***b*, they are amplified by amplifiers **11** and **12** to a magnitude comparable to that of signal e_E. Amplifier **11** provides an output signal $e_B = \epsilon P_B$. Output signal $e_R = \epsilon P_R$ representing the rolling load P_R is converted into a signal Ce_R by means of multiplier **13**. Comparator **14** functions to compare these signals to obtain a signal e according to the following equations

$$Ce_R - e_B - e_E = e$$

or

$$C\epsilon P_R - \epsilon P_B - \epsilon K_B S_e = e$$

Difference signal e is applied to pressure regulator **15**, which regulates the pressure of the fluid supplied to fluid pressure cylinder **9** so as to reduce signal e to zero. As the pressure regulator, an electric oil pressure type servo valve is preferred. The regulator operates to increase or decrease the fluid pressure supplied to fluid pressure cylinder **9** in response to the magnitude and polarity of signal e.

Operation of fluid pressure cylinder **9** results in variation of P_R and P_B and hence in variation of the output from comparator **14** so that the pressure of the fluid supplied to hydraulic cylinder **9** is adjusted until output signal is reduced to zero.

Thus, according to the novel control system, effects of roll displacement can be eliminated, thus providing products of uniform longitudinal thickness.

It should be understood, of course, that the foregoing disclosures relates to only a preferred embodiment of the invention and that it is intended to cover all changes and modifications of the example of the invention herein chosen for the purposes of the disclosure, which do not constitute departures from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A control system for a rolling mill including a pair of working rolls, a pair of back-up rolls, and mill screws for adjusting the position of said back-up rolls, said control system comprising a hydraulic cylinder associated with one of said back-up rolls, a first load cell associated with at least one of said mill screws for generating an electrical signal representing the force exerted thereby, a second load cell associated with the other of said back-up rolls to provide an electrical signal representing the rolling load, means associated with said working and back-up rolls for generating an electrical signal representing the distance between the axes of said working and back-up rolls and means to compare said electrical signals to control said hydraulic cylinder.

2. The control system according to claim **1** wherein said means to compare said electrical signals comprises a comparator used to provide an output signal corresponding to the difference between said three electrical signals, and said output signal controls the pressure of the fluid supplied to said hydraulic cylinder so as to reduce said output from said comparator.

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