APPARATUS FOR STABILIZING GAGEMETER CONTROL OF ROLLING MILLS

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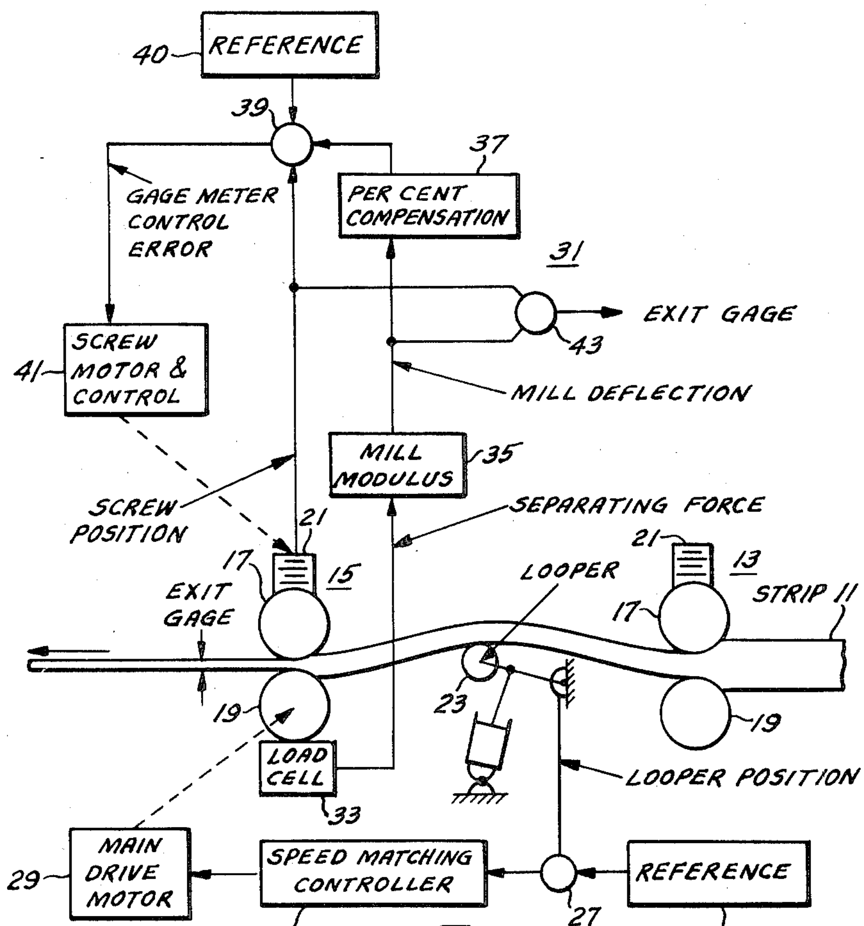

FIG. 1

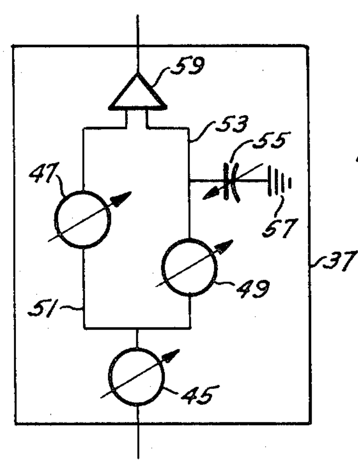

FIG. 2

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APPARATUS FOR STABILIZING GAGEMETER CONTROL OF ROLLING MILLS

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U.S. Cl. 72—8 3 Claims

ABSTRACT OF THE DISCLOSURE

In order to stabilize a gagemeter control system for rolling mills the roll force deviation signal is partially delayed for a finite period sufficient to allow reaction of the loopers to reestablish correct tension in strip in the mill after a change in screwdown has been initiated.

BACKGROUND OF THE INVENTION

So-called "gagemeter" gage control systems such as basically disclosed in Pat. No. 2,680,978 to Hessenberg are widely used in the control of rolling mill stands. The performance of these gagemeter systems deteriorates as the strip thickness decreases and the strip width increases. As strip material is reduced in gage the load cell signals which are used to calculate the spring of the mill stands become more and more similar to the screw position signals required to compensate for the spring until with very thin material, and particularly with thin and wide material, the load cell signal changes by almost exactly the same amount with a change in screwdown as the screw position signal changes. When this somewhat ambiguous condition is reached sudden surges of feedback, such as occur when large corrections of gage are attempted, may, in combination with slight errors in adjusting the relative magnitude of the roll force and the screw position signals cause the screwdowns to run away, either in the up or the down direction. To minimize the tendency of a gagemeter stand to run away when adjusted to control gage closely for a thin and wide product it has been customary to adjust the ratio of the roll force and screw position signals to give substantially less screw movement than is desired to compensate for mill spring. The gage control performance is, however, thereby compromised since the strip gage rolled by the use of a gagemeter compensated in this manner is for example always slightly heavier than desired when a downward screw motion is required. In addition even with such a reduction of compensation, on many hot strip mills the "gagemeter" control must be turned off on the last one or two stands on light gage orders to avoid cobbles and wrecks.

I have discovered that a great deal of the instability of previous "gagemeter" control systems has arisen because of the relatively slow reaction of the associated looper control systems. Because the loopers comprise fairly massive mechanical systems the tension of the strip regulated by the looper control cannot be adjusted instantaneously. In a standard gagemeter system, the screwdown of the rolling stand will move down in response to disturbances such as local cold or other hard spots in the strip. In a tandem mill when the screws move down there is a temporary reduction in incoming tension. This leads to an immediate increase in roll force in the rolling stand for two reasons: (1) there is a substantial increase due to the increased reduction and (2) there is a substantial increase due to the reduction in strip tension because the tension stress in the roll bite no longer aids the stand to make a reduction in strip thickness. The latter increment of increased roll force increases the screw movement beyond that required by the gagemeter control to remove all excess gage. This increment of roll force, however, is only

temporary until the looper has time to react and restore proper tension to the strip. Meanwhile, however, the additional screw movement and roll force incident to the looper delay may have thrown the system into an unstable condition and caused the screwdown to run away, or, if the increase has not been sufficient to initiate a runaway screwdown, it will cause over-correction of the screwdown, and probable hunting of the control system. As mentioned supra this tendency to instability and hunting of the system may be alleviated by adjusting the ratio of screwdown movement to indicated gage deviation so that the screw movement is sufficient only to remove a portion, such as for example 95%, of the excess gage of the strip. This, however, is undesirable as it in effect means that much off-gage strip is produced.

SUMMARY OF THE INVENTION

I have discovered that the foregoing disadvantages of a gagemeter system can be overcome by the employment of a time delay circuit to delay a portion of the roll force signal change for a time period sufficient to allow the strip tension to be substantially restored to its desired regulated value after a change in screwdown has been initiated by the gagemeter system.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a gagemeter control system for the last stand of a tandem rolling mill according to the present invention.

FIG. 2 is a diagrammatic illustration of a suitable time delay circuit for the gagemeter control arrangement shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 a strip **11** is shown passing through the last two rolling stands **13** and **15** of a tandem rolling mill. Each of these two rolling stands comprises an upper work roll **17** and a lower work roll **19**. A screwdown mechanism **21** is provided on each stand to move the upper rolls **17** to determine the opening between the rolls **17** and **19**. A looper **23** is located between the rolling stands **13** and **15** to take up slack in the strip **11** as shown and to provide a looper position signal to a speed matching controller **25** through a summing point **27** which may comprise any suitable algebraic computer amplifier element. A predetermined reference signal representing the desired position of the looper is also directed from a reference signal generating means **26** to summing point **27** for comparison with the actual position signal. The speed matching controller **25** regulates the speed of main drive motor **29** which drives the rolls of rolling stand **15**. The speed of rolls **17** and **19** of stand **15** is increased through the action of the looper control system if looper **23** detects excess slack between stands **13** and **15** and is decreased if looper **23** detects less slack and consequently more tension than is desired between stands **13** and **15**.

A gagemeter control system **31** is provided for stand **15** comprising a load cell **33** positioned under the lower work roll **19** which load cell **33** directs a signal proportion to the separating force between the rolls to a single function control element **35** where it is converted to a mill deflection signal through the application of the standard mill deflection formula based on Hook's Law. The mill deflection signal is then passed into a time delay control element **37** where a portion of the signal is delayed a predetermined period sufficient to allow reaction of the looper system to maintain proper tension before the signal is passed on as a compensated mill deflection signal to summing point **39** where the compensated mill deflection signal is algebracially added to a screw position signal derived from any suitable screw position detector and signal generator associated with the screwdown mechanism **21** and stand **13**. The combined signals are also compared at the summing point **39** with a reference signal from a reference signal generating means **40** representing the desired gage of strip leaving the mill. Summing point **39** may comprise any suitable type of computer element operative to add the three signals together algebraically or otherwise suitably combine them to provide a gage error signal representative of the departure of the opening between the work rolls—and consequently the strip passing through the rolls—from the desired gage of the strip as it leaves the stand. The gage error signal is then directed to screw motor and control **41** which controls and operates the screwdown mechanism **21** to adjust the opening between the rolls **17** and **19** of stand **15** to provide correct strip gage.

The mill deflection signal derived from single function controller **35** is also directed before reaching time delay control element **37** to summing point **43** where it is combined with a portion of the screw position signal derived from screwdown mechanism **21** to provide a combined signal proportional to the actual opening between the rolls **17** and **19** of the rolling mill. The combined signal may be applied to any suitable gage or meter to represent to the operator the actual opening between the rolls of the stand and consequently the actual strip gage being rolled at any given time.

One suitable form of time delay control element **37** is shown in FIG. 2. The mill deflection signal from single function controller **35** shown in FIG. 1 is directed to a variable percent compensation potentiometer **45** which is adjusted to provide a signal compensated as to the amount of roll movement which will be made in response to a load cell signal of any given amount. The movement of the rolls may thus be controlled to provide any desired percentage of the total movement which is normally called for by any given load cell signal. This signal is then split between two variable signal distribution potentiometers **47** and **49** on legs **51** and **53** respectively of the time delay circuit. A variable capacitor **55** is connected to leg **53** of the time delay circuit and ground **57**. Both legs of the circuit then lead to a summing amplifier **59** where the signals from legs **51** and **53** are combined, amplified and directed from time delay control element **37** to summing point **39** shown in FIG. 1.

When a mill deflection signal is received in time delay element **37** from single function computer element **35** the signal is brought to the desired strength by prior adjustment of the setting of variable potentiometer **45** and is then split between legs **51** and **53** of the time delay circuit. The proportion of the signal passing through each leg will be determined by the settings of distribution potentiometers **47** and **49**. The signals then pass to summing amplifier **59** where they are recombined and passed on as a single amplified and compensated mill deflection signal to summing point **39**. The portion of the mill deflection signal passing through leg **51** of the time delay circuit passes through the control without any change in its time dependent signal characteristics but the portion of the mill deflection signal passing through leg **53** of the time delay circuit is partially deflected into variable capacitor **55** until the capacitor **55** is fully charged. The length of time necessary to build up a full charge on capacitor **55** may be varied by varying the capacitance and is selected to be substantially the time necessary for the looper control to restore full tension after a change in screwdown has occurred. Since the buildup in the charge on capacitor **55** is grandual the increase in the signal passing through leg **53** of the time delay circuit will also be gradual. The total signal through both legs thus will quickly reach an initial value as the signal passes freely through leg **51** and will more gradually reach a final value along a decreasing curve as the remainder of the signal passes through leg **53** and the charge in capacitor **55** builds up. Preferably the variable potentiometers are adjusted so that the portion of the signals which pass throu;gh the two legs of the time delay circuit are proportional to the amount of the total mill deflection signal which derives from the original error in strip gage and the amount of the total mill deflection signal which derives from the temporary increase in load in the mill as a result of temporary loss of strip tension before the looper mechanism can react to restore proper tension. While such a relation of the signals will provide the most desirable results, excellent results will also be had if the entire mill deflection signal is partially delay. This may be done using the same simple time delay circuit shown in FIG. 2 merely by adjusting variable potentiometer **47** so that no, or substantially no, signal passes therethrough. This in effect provides a single rather than a split time delay circuit and the entire mill deflection signal passes through leg **53** of the time delay circuit so that substantially the entire signal is subjected to the effects of capacitor **55**. This provides a single continuously increasing compensated mill deflection signal which increases exponentially at a decreasing rate until the capacitor **55** is fully charged. Such a simplified circuit may be desirable for special purposes. Other suitable time delay circuits and other possible locations of the time delay in the gagemeter control loop will occur to one skilled in the art but I have found that the illustrated arrangement provides the most desirable results.

The invention has been illustrated with respect to use on the last stand of a tandem rolling mill and will be found to be most useful on the last two stands of tandem rolling mills as these are normally the most unstable stands due to the thinner gage strip passing through them. The invention, however, may also be used advantageously on the other stands of a tandem mill. If the invention is used on one of the stands of the mill having a looper located on both sides of the stand rather than on the last stand of the mill the time delay of part of the mill deflection signal will compensate not only for the effects of the looper immediately preceding the mill stand but also for the effects of the looper following the mill stand and the time delay will be adjusted to have a period which will compensate for the delay of both loopers. Ordinarily, of course, this delay will be similar for both loopers and will occur simultaneously. The looper preceding the mill stand ordinarily has the greatest effect on the gage of the strip passing through the mill stand due to the fact that the strip passes directly to the bite of the roll on this side.

While the invention has been described with respect to operation during the downward movement of the screws of a rolling mill—since this is a more crucial operation—it is also effective during upward movement of the screws of a rolling mill to delay the decay of the roll force signal until the loopers have an opportunity to react and decrease excess tension between the rolling stands resulting from the increase in gage of the strip. Too great an increase in tension between the rolling stands could result in necking down of the strip in a hot mill or the tearing of strip in a cold mill.

I claim:

1. An automatic gage control system for a rolling stand of a tandem rolling mill having a looper speed control means comprising:

(a) load cell means to provide a first signal proportional to the separating force between the rolls of said stand,

(b) means to provide a second signal nominally proportional to the separation between the rolls of the said stand,

(c) reference signal means to indicate the desired separation between the rolls of the stand by a third signal,

(d) means to convert said first signal into a fourth signal proportional to the increased separation between the rolls of the first rolling stand due to the yield of the mill under the separating force,

(e) means to combine said second signal with said fourth signal and balance against said third signal to provide a fifth signal proportional to the error between said desired roll position and said actual roll position;

(f) means responsive to said fifth signal to operate the screwdown of the said rolling stand, and

(g) means to delay the full effects of the first signal from reaching said means (e) for substantially the time it takes the looper speed control system associated with said mill stand to react to restore tension lost between said rolling stand and any adjacent rolling stand when said screwdown is operated by means (f).

2. The automatic gage control system according to claim **1** wherein the effects of said first signal are delayed by delaying said fourth signal by a delay circuit means.

3. The automatic gage control system according to claim **2** wherein said delay circuit means includes a split circuit in which the fourth signal is split into a completely undelayed porton substantially proportional to the amount of the signal derived from an original error signal and a

portion at least partially delayed proportional to the proportion of the signal deriving from increased gage resultant upon loss of strip tension between the rolling stands as the screwdown is operated to remove the original error signal.

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MILTON S. MEHR, Primary Examiner

U.S. Cl. X.R.

72—205, 16

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,550,414 Dated December 29, 1970

Inventor(s) Harold A. List

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading to the printed specification, after line 5, insert -- assignor to Bethlehem Steel Corporation, a corporation of Delaware --.

Signed and sealed this 25th day of May 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents