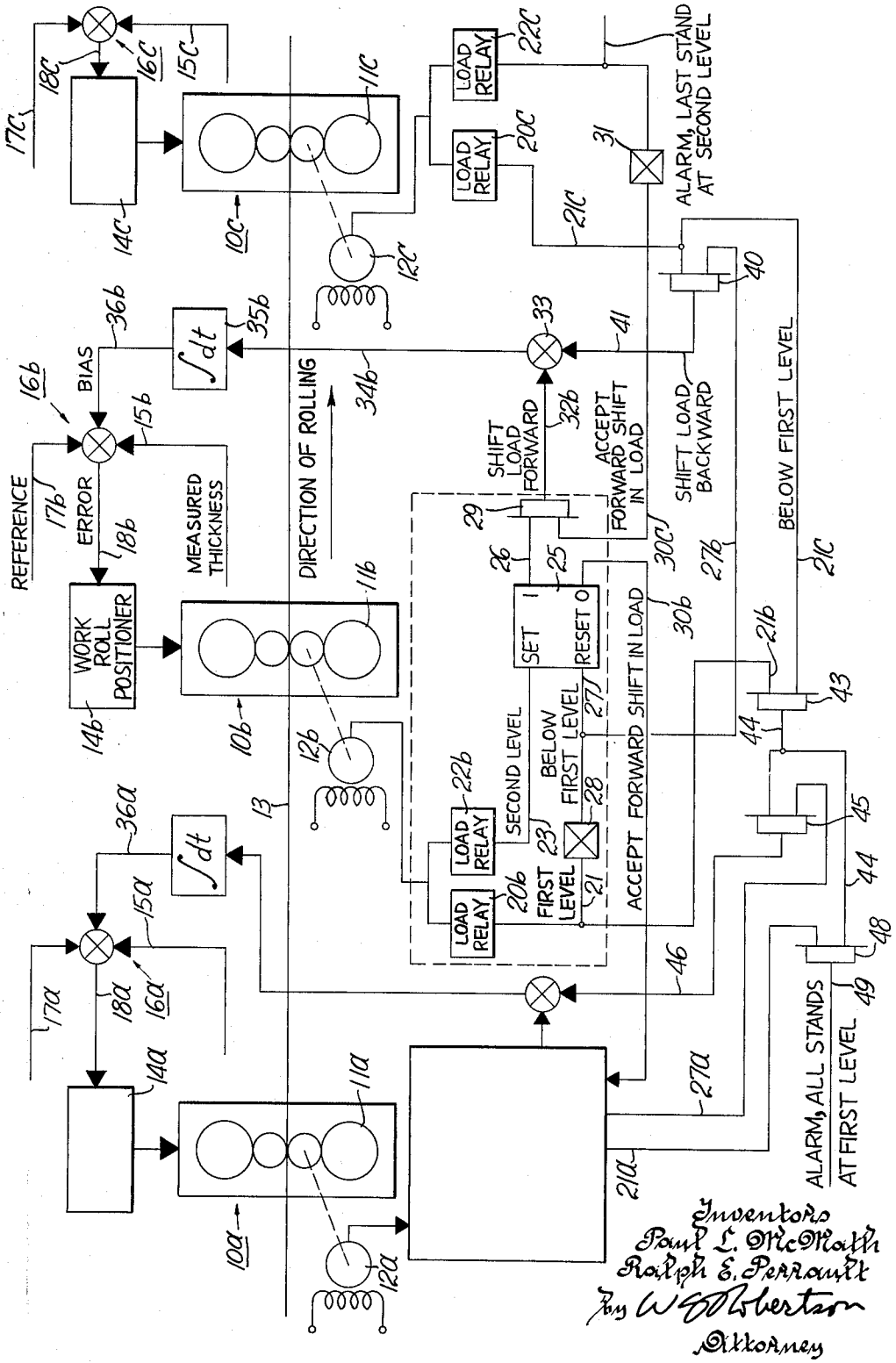
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MOTOR LOAD DISTRIBUTING SYSTEM FOR METAL ROLLING MILL

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Inventors
Paul L. McMath
Ralph E. Perrault
by W. E. Robertson
Attorney

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MOTOR LOAD DISTRIBUTING SYSTEM FOR METAL ROLLING MILL

Paul L. McMath, Hales Corners, Wis., and Ralph E. Perrault, Monrovia, Calif., assignors, by mesne assignments, to Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

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This invention relates to a control for distributing the load on a group of electric motors. More specifically, this invention relates to a control for distributing the load on the motors that drive the work rolls in a metal rolling mill with automatic gauge control.

Some automatic gauge controls for metal rolling mills measure the thickness of the strip being rolled, compare the measured thickness with a reference thickness, and order any appropriate changes in the force of the work rolls on the strip. The reference thickness decreases from stand to stand in the direction of rolling to cause each stand to contribute part of the total reduction in the strip thickness. Since the load on a work roll drive motor depends on the reduction at its stand, the drive motors share the mill load according to the relative values of the reference thicknesses. The automatic gauge control at each stand varies the work roll force as various factors cause the gauge to differ from the reference, and it gradually increases the work roll force during the rolling process as the strip cools and becomes harder. This invention is particularly concerned with the problem of keeping a satisfactory distribution of the load on the work roll drive motors.

One object of this invention is to sense when the load on the work roll drive motor of one reducing stand is at a predetermined high level and to operate the reducing stand to shift some of this load to the next stand. Another object of the invention is to sense when the next stand is loaded at a predetermined high level and to prevent shifting the load forward to the next stand in this situation.

Another object of this invention is to sense the load on the last stand with automatic gauge control and to operate the preceding reducing stands to shift the load backward before the last stand reaches a preset high load level. Another object of the invention is to prevent shifting the load backwards to stands that are already heavily loaded.

Another object of the invention is to provide a warning to the mill operator whenever all of the stands with automatic gauge control have reached a level at which it is undesirable to shift the load backward from stand to stand and to prevent further forward shift.

Another object of the invention is to provide a warning to the mill operator when none of the stands can accept additional load from the last stand, and the load on the last stand has increased to a second preset high level.

The drawing and the detailed description of the invention will suggest other objects and advantages of this control.

The control of this invention senses two load conditions at each mill stand that has automatic gauge control. The first level warns that the load is becoming high but the motors still have capacity to drive the rolls as the roll force is increased. The second level indicates that the load should not be increased farther. For example, the second level may be set just below the level that protective devices would trip out the work roll drive motor. In response to a signal indicating the second level, the control operates the work roll positioning mechanism to reduce the roll force until the load falls to the

first level. The reduction in load at this stand must be made up at the following stands if the material is to have the desired thickness, and the automatic gauge controls cause the load to be shifted ahead from the stand that is partially unloaded. When the load on the mill increases so much that the last stand reaches the first load level, the control shifts the load backwards, in a preset sequence, to any stand that is not already operating at the first level. In this way the control keeps any stand from becoming overloaded, and it assures that every stand will be highly loaded before the last stand is operated by its automatic gauge control above the first load level.

In the drawing, the single figure is a schematic of a rolling mill with automatic gauge control and the control of this invention.

The mill and the automatic gauge control

The mill that the drawing illustrates has three reducing stands 10 which have automatic gauge control. Stands 10 are suffixed *a*, *b* and *c* in the direction of rolling, and these suffixes are used to distinguish between equivalent components used at more than one reducing stand. Stands 10 represent the first, next to the last, and last stands and illustrate intervening stands with automatic gauge control. Other stands with or without gauge control (not shown) may be located in any position. Each stand 10 has work rolls and backup rolls 11 that are driven by a motor 12 to pull a strip 13 through the mill. A device 14 for each stand is controlled to position the work rolls 11 and apply force through the work rolls on strip 13. Each stand 10 has a thickness measuring device (not shown) that produces a thickness signal 15. The automatic gauge control of each stand has a means 16 that compares gauge signal 15 with a reference 17 (combined with a reference biasing signal that will be described later) and produces a thickness error signal 18.

In response to signal 18, roll positioning device 14 varies the work roll force to maintain the reference gauge. As will be explained later, the control of this invention biases the reference 17 to adjust the load on motors.

The components of the mill and the automatic gauge control that have been described are well known and they have been described sufficiently to suggest the application of the control of this invention to various types of mills and automatic controls.

The forward load shift

The control of this invention includes for each stand 10*a*, 10*b*, and 10*c*, a load sensing relay 20 that produces a preset first load level signal 21 and a load sensing relay 22 that produces a preset second level signal 23. Preferably, the relays 20, 22 are adjustable by the mill operator so that signals 21, 23 correspond to the characteristics of the associated stand 10. As will be explained, the signals 21, 23 are used to indicate whether a stand should shift some of its load to the other stands and whether the stand could accept part of the load from other stands. Stands 10*a* and 10*b* have identical components that operate in response to signals 21, 23 to shift the load forward. These components are shown in detail inside the dotted lines for stand 10*b* and shown by a box for stand 10*a*. (Since the last stand 10*c* cannot shift its load forward, its control is different from the control of the preceding stands 10*a*, 10*b*.)

As the controls for stand 10*b* illustrates, the second level signal 23 sets a device 25 such as a flip-flop to produce a signal 26 that indicates that the motor has reached the second level. Device 25 maintains output 26 until it is reset even though the load falls below the second level and signal 23 is removed. A reset signal

27 (the complement of signal 21) is developed from first level signal 21 by means of a NOT gate 28 and is applied to the reset input of device 25 to reset device 25 when the load falls below the first level. Preferably, signal 26 is applied to reduce the load on the stand only if the next stand is not at the second level. An AND gate 29 receives signal 26, and it receives a signal 30c that is derived from the second level signal 23 of the last stand with automatic gauge control, 10c, by a NOT gate 31 to indicate when the load of stand 10c is below the second level. AND gate 29 produces an output 32 when the load on stand 10b should be reduced to the first level and this action will not excessively load the last stand 10c. The complementary output of device 25 provides a suitable signal 30b for controlling a corresponding AND gate in the box representing part of the control of the preceding stand 10a.

Signal 32 is transmitted to a device 33 that combines signal 32 and a signal that will be described later and produces a signal 34 that indicates that the load on the stand should be changed. An integrator 35 receives signal 34 and produces an output 36 that is combined with reference signal 17 in automatic gauge control device 16. Device 33 may comprise the input circuitry of integrator 35. So long as device 25 is set and the stand 10c is below its second level, signal 34 operates integrator 35 to change the reference bias signal 36.

Suppose that stand 10b is operating below the first level and that the load on its motor 12 increases sufficiently to actuate load sensing relay 22 to set device 25 and energize output 26. If the last stand 10c is at level two, the absence of a signal at input 30c to AND gate 29 prevents AND gate 29 from energizing its output 32. In this situation device 25 would maintain its output 26 energized until the load on stand 10c is reduced below level two or until some other factor causes the load on stand 10b to fall below the first level. When both inputs 26 and 30c are energized, AND gate 29 energizes output 32 and input 34b of integrator 35b is energized in a polarity for integrator 35b to begin increasing reference bias signal 36b. In response to the increase in reference bias signal 36b, roll positioner 14b opens the work rolls 11 of stand 10b and thereby reduces the load on motor 12. When the load has been reduced below the first level, load sensing relay 20b cooperates with NOT gate 28 to energize reset input 27 of device 25 and thereby deenergize input 34b of integrator 35b. Integrator 35b then maintains its output 36b at the level that reduced the load on the stand 10b to below the first level. After device 25 is reset, the automatic gauge control of stand 10b is free to increase or decrease the work roll force in response to variations in thickness signal 15.

Preferably as the drawing indicates, components 20, 22, 25, 28, 29, 33 and 35 are well known static logic elements. If desired these components may be made up of electromechanical load sensing relays 20, 22, a third relay in device 25, and their contacts. Device 25 may comprise the third relay with its coil connected to be energized by a pair of normally open contacts on relay 22 (represented by signal 23) in parallel with the series combination of a pair of normally closed contacts on relay 20 (represented by NOT gate 28) and a normally open pair of contacts on the relay of device 25. The relay of device 25 also operates a pair of normally open contacts represented by output 26 and a pair of normally closed contacts represented by output 30b. AND gate 29 may comprise the series combination of a pair of normally open contacts already mentioned on the relay of device 25 and a pair of normally closed contacts (represented by NOT gate 31) on the second level relay 22c of the last stand 10c. Integrator 35 may comprise, for example, a reversible motor connected to drive a potentiometer, an integrating amplifier, or a digital counter. Device 33 may comprise the input to integrator 35.

The backward shift of the load

The control that has been described for opening the work rolls to shift the load forward from stands 10a and 10b is not applied to the stand 10c because the strip 13 would leave the mill over gauge. The control for the last stand 10c responds to the first level signal 21c from load sensing relay 20c to operate other components to shift the load backwards. These components are illustrated in the drawing by AND gates. The arrangement of these gates is intended to present the functional relationship of the components in a verbal form and to suggest connections of contacts on the relays 20, 22. Variations of this specific logic network will be apparent from well known design techniques.

An AND gate 40 receives a first level signal 21c from the stand 10c and the complement first level signal 27b from stand 10b and produces a signal 41 whenever the stand 10c is loaded to the first level and stand 10b is not loaded to the first level. Signal 41 energizes input 34b of integrator 35b in a polarity to reduce reference bias signal 36b and cause work roll positioning device 14b to increase the roll force at stand 10b. Output 41 of AND gate 40 will remain energized until the work roll force at stand 10b has increased sufficiently to bring the load on the stand 10c below the first level or until the load on stand 10b has increased sufficiently to actuate load sensing relay 20b and thereby deenergize input 27b to AND gate 40.

When both the stand 10c and stand 10b are at the first level, the control tries to increase the load on stand 10a. An AND gate 43 receives the first level signals 21b and 21c from stands 10b and 10c and energizes an output 44 whenever both stand 10b and stand 10c are at the first level. Output 44 energizes one input of an AND gate 45 and a complement first level signal 27a from stand 10a energizes another input of AND gate 45. When both stand 10b and stand 10c are at the first level and stand 10a is below the first level, AND gate 45 energizes its output 46 in a polarity to reduce reference bias signal 36a and thereby increase the load on stand 10a.

An AND gate 48 receives a first level signal 21a from stand 10b and signal 44 from AND gate 43 and energizes an output 49 whenever the stands 10a, 10b, and 10c are at level one. Output 49 operates an alarm that tells the mill operator that each stand is operating at the first level. The mill operator may consider some corrective action not provided by this control, or he may allow the mill to operate without change since the motors 12 still have capacity for increased load up to the second level.

Preferably, gates 40, 43, 45 and 48 comprise static logic devices. If desired, the gates may comprise contacts on electromechanical relays 20, 22. AND gate 40 may comprise the series combination of a pair of normally open contacts on the relay 20c of stand 10c and a pair of normally closed contacts (indicated by NOT gate 28) on the relay 20b of stand 10b. AND gate 43 may comprise a pair of normally open contacts on each first level relay 20b, 20c, of stands 10b, 10c. AND gate 45 may comprise the series combination of a pair of normally closed contacts on the relay 20a of stand 10a, a pair of normally open contacts on relay 20b of stand 10b, and a pair of normally open contacts on the relay 20c of the stand 10c. AND gate 48 may comprise the series combination of a pair of normally open contacts on each relay 20 of stands 10a, 10b, 10c.

The control of this invention and the automatic gauge control will maintain the desired gauge without overloading any of the motors until the load on the last stand in the automatic gauge control reaches the second level. Output 23 of the second level sensing relay 22 of the last gauge controlling stand operates an alarm that tells the mill operator that this stand is operating near its maximum load. The operator may elect to let the mill run and to rely on safety devices to protect the motor, or he

may elect other procedures not provided by this control.

The sequence that has been described of shifting the load backwards in the reverse order of the reducing stands is somewhat arbitrary and the AND gates **40**, **43**, **45** and **48** may be connected to shift the load backwards in any desired sequence.

As the control has been described so far, the first level signal is used for the two independent functions of establishing the portion of the load that the control shifts forward and establishing the level at which the stand is isolated from the backward shift of the load. If desired, a stand **10** (except the last stand with automatic gauge control) may be provided with two load responsive relays where the single relay **20** is illustrated. One would provide reset input signal **27** to limit the forward shift of the load and one would provide the complementary signals **21** and **27** to control the backward shift of the load.

This description of the invention will suggest to those skilled in the art a variety of devices that are suitable for the functional boxes shown in the drawing and variations in the relation of the components within the spirit of the invention and the scope of the claims.

Having now particularly described and ascertained the nature of our said invention and the manner in which it is to be performed, we declare that what we claim is:

1. A control for a selected last stand and a plurality of preceding stands, all with automatic gauge control, in a metal rolling mill, comprising,

means connected to sense the work roll drive motor load of each of said stands to produce a first signal for each of said preceding stands when the motor load is at or above a preset first level and to produce a second signal for each of said stands when the load is at or above a preset second level,

flip-flop means for each of said preceding stands connected to be set by said second signal and to be reset by the complement of said first signal of the associated stand,

means for each of said preceding stands connected to respond to the output of the flip-flop of the associated stand and the complement of the second signal of the next stand in the direction of rolling to produce a binary control signal, and

integrator means for each of said preceding stands connected to respond to the control signal of the associated stand and to operate on the automatic gauge control to reduce the motor load at the associated stand to below said first level after the load rises to the second level.

2. A control for a selected last reducing stand and a plurality of preceding stands, all with automatic gauge control, in a metal rolling mill, comprising,

means for each of said stands connected to sense the load on the work roll drive motors and to produce a signal when the motor load at the associated stand reaches a preset level, said load sensing means on each of said preceding stands having a flip-flop connected to be set when the motor load reaches a preset relatively higher level and to be reset when the load reaches a relatively lower level,

means for each of said preceding stands connected to respond to the signal of the associated stand and the complement of the signal from the next stand in the direction of rolling to produce a control signal, and

means responsive to said control signal to operate on the automatic gauge control of the associated stand to reduce the load on the associated stand by a preset amount.

3. A control for a selected last reducing stand and a plurality of preceding stands, all with automatic gauge control, in a metal rolling mill, comprising,

load sensing means for each of said stands connected to sense the work roll drive motor load and to produce a first signal when the load rises to a first preset level,

each said load sensing means for said preceding stands produces a second signal when the motor at the associated stand reaches a second level that is higher than the associated first level,

means responsive to said first level signal from said last stand and to the complement of said first level signal from a first of said preceding stand when said last stand is at or above its first level and said first preceding stand is below its first level, and

means responsive to the complement of said first signal of a second of said preceding stands and said first signals of said first and last stands to shift part of the load on said last stand to said second preceding stand when said first preceding stand and said last stand are at or above said first level and said second preceding stand is below said first level,

means for each said preceding stand for operating on the automatic gauge control of the associated stand to shift the load forward from the associated stand when its load reaches its second level,

said means for shifting the load forward comprising a flip-flop that is connected to be set by the associated second signal and to be reset by the complement of the associated first signal, and

an integrator connected to receive an output of said flip-flop to increase the reference thickness at the associated stand until the load at the associated stand has fallen below its first level.

4. A control according to claim **3** in which said means that operates to shift the load forward includes

a logic gate for each of said preceding stands, each gate being connected to receive an output from the flip-flop of the associated stand and each except the next to said last being connected to receive a complementary signal from the flip-flop of the next preceding stand in the direction of rolling, the flip-flop of said next to the last stand being connected to receive the complement of the second level signal of said last stand,

whereby each said gate energizes the associated integrator only when the associated stand is at or above its second level and the next stand in the direction of rolling is not at its second level or operating to shift the load forward.

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