ROLLING MILL AUTOMATIC SLOWDOWN CONTROL

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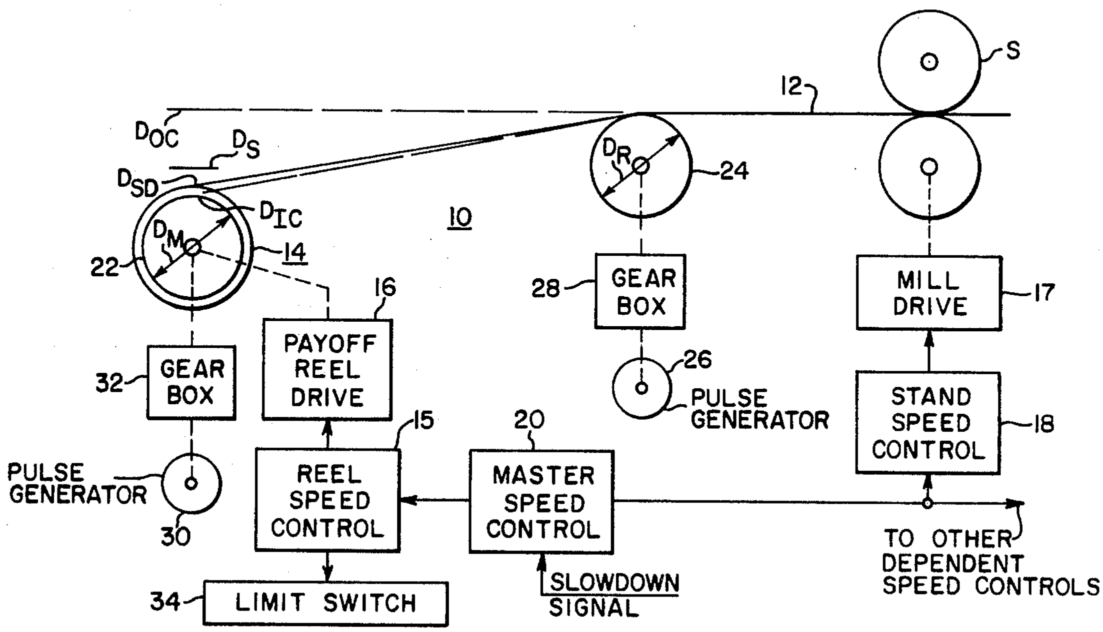
FIG. 1.



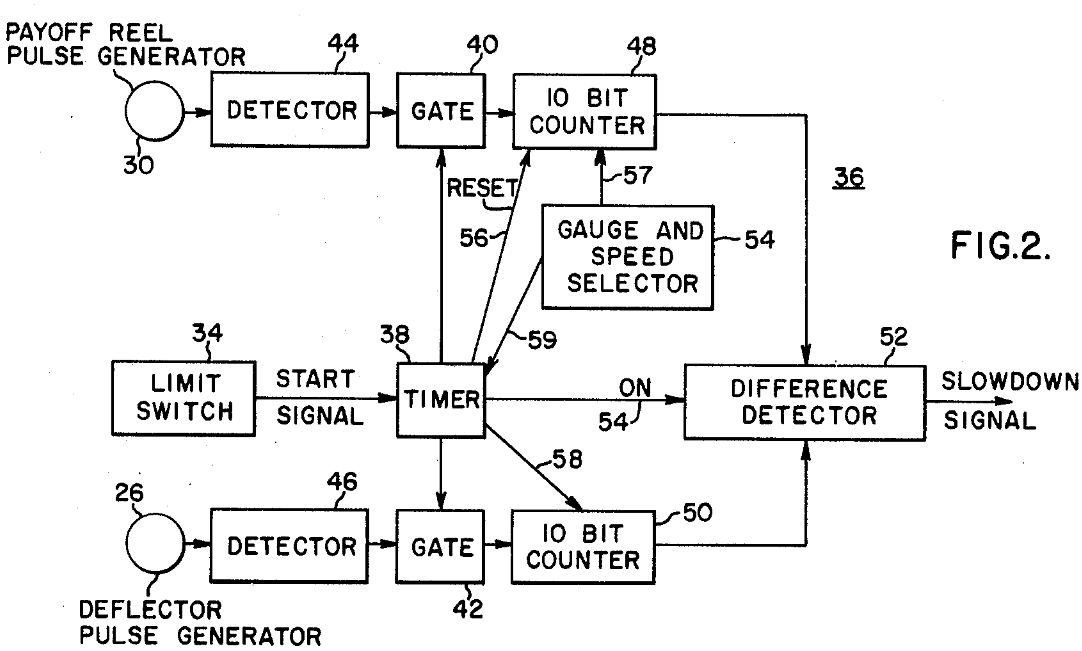


FIG. 2.

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ROLLING MILL AUTOMATIC SLOWDOWN CONTROL

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ABSTRACT OF THE DISCLOSURE

A strip mill automatic slowdown control includes an arrangement for detecting and comparing the speeds of a payoff reel and an entry deflector roll. When the two speeds reach a predetermined relation, mill slowdown is initiated. A selector control is adjusted according to strip gauge and mill speed to allow delayed mill slowdown for lighter gauge and/or slower mill run speed to allow earlier mill slowdown for heavier gauge and/or faster mill run speed.

BACKGROUND OF THE INVENTION

The present invention relates to control systems for rolling mills and more particularly to rolling mill automatic slowdown controls.

In the operation of a rolling mill such as a non-reversing tandem cold steel strip reduction rolling mill, a strip is unwound from a payoff reel, threaded through the roll stands and wound on a windup reel. Once the threading operation is completed, the mill is accelerated from thread speed to a preselected run speed and operated at the run speed until some operating point at which mill deceleration is initiated to provide safe tailoff, i.e., to prevent the end of the strip from going through the mill at an excessive speed. Usually, the tailoff speed is set equal to the thread speed.

Similar operating conditions apply to reversing type cold steel rolling mills and reversing rolling mills for materials other than cold steel strip. In the reversing type mill, a single roll stand is usually employed and the described startup, run and slowdown sequence is effected for each pass in the mill operation.

In all cases, mill productivity is optimized if the mill is operated at the highest possible average speed. In turn, maximum average speed requires slowdown initiation at the latest point in time at which safe tailoff is enabled. The optimum slowdown point depends principally upon the operating run speed of the mill and the number of strip wraps required on the payoff reel to enable mill deceleration to the tailoff speed just as the strip tail end is coming off the payoff reel and entering the mill.

Slowdown initiation for optimal or near optimal performance is often problematical particularly in nonreversing mills because different payoff reels supplied to a mill typically have different and unknown numbers of strip wraps resulting for example from different length and different gauge payoff strips. Even in reversing mills, the slowdown initiation problem typically applies although it is usually limited to the first strip pass while conventional wrap counters enable subsequent passes to be controlled optimally or nearly optimally. Where a programmed digital computer is installed for mill control, highly accurate selection and detection of a slowdown payoff coil diameter builddown value can be employed reliably to initiate accurately optimized mill slowdown. However, a computer cannot always be economically justified for the control of a reversing or a nonreversing rolling mill.

SUMMARY OF THE INVENTION

An economic automatic mill slowdown control includes means for detecting a condition representing the payoff coil builddown diameter value over at least a predetermined builddown diameter range. A selector control is set as a function of strip gauge and as desired also as a function of mill run speed in order to define a builddown diameter value at which mill slowdown can be achieved with improved productivity on an economic basis. The slowdown control initiates mill slowdown including payoff reel slowdown when the selector control defined payoff coil slowdown builddown diameter value is reached.

It is therefore an object of the invention to provide a novel rolling mill automatic slowdown control which enables improved mill productivity to be achieved on an economic basis.

A further object of the invention is to provide a novel rolling mill automatic slowdown control which enables improved mill productivity to be achieved in existing or newly constructed rolling mills where a computer is not economically justified or not economically applied to slowdown control.

These and other objects of the invention will become more apparent upon consideration of the following detailed description along with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a schematic diagram of a payoff reel associated with a typical tandem cold steel reduction rolling mill; and

FIG. 2 shows a schematic diagram of a control arranged in accordance with the principles of the invention to effect automatic slowdown of a rolling mill such as that shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

More specifically, there is shown in FIG. 1 a typical rolling mill **10** having in this case a plurality of conventional nonreversing tandem roll stands S (only one shown) through which cold steel strip **12** is transported for gauge reduction. In other cases, a mill in which the invention is to be embodied could be the reversing type and/or it could be arranged to roll materials other than cold steel strip.

The strip **12** is supplied from a payoff reel **14** which is suitably driven and speed controlled such as by a drive **16** operated by a CEMF speed control **15** to make the reel speed correspond to the mill speed as the coil builddown diameter increases with the uncoiling of the strip wraps from the reel **14**. Mill stand speeds are individually controlled by conventional stand speed controls **18**, and a suitable master mill speed control **20** coordinates the payoff reel speed with the mill speed as the mill is operated under threading, accelerating, running and decelerating conditions.

Typically, the reel **14** would have a mandrel **22** having a diameter D_M equal to the inner coil diameter D_{IC} and common to that of other mill mandrels. The inner coil diameter D_{IC} can therefore be assumed to be constant from payoff reel to payoff reel of operation, except in those cases where the rolling mill plant is provided with two or more sets of mandrels with the mandrel sets having different diameters. In that event, some slowdown control adjustment must be made when switching from one mandrel set to another set as subsequently described more fully.

At the entry side of the mill **10**, there is also located a conventional free running entry deflector roll **24** which aids in guiding the strip **12** to the first stand S and which functions in the slowdown control system as subsequently more fully described. To provide for slowdown control functioning, signal generator means preferably in the form of a pulse generator **26** such as the type sold under the trade name Rotrac is coupled through gearing **28** to the deflector roll **24**. Similarly, signal generator means preferably in the form of a pulse generator **30** such as a Rotrac is coupled through gearing **32** to the payoff reel **14**. For purposes subsequently noted, it is also noted that a conventional cam type limit switch **34** is in this case cam operated by a motor operated rheostat (not shown) which is included as a part of the payoff reel CEMF speed control **15**.

In operation, the reduction rolling mill **10** is brought to thread speed and the head end of the strip **12** is then threaded through the roll stands and into the downcoiler (not shown). The mill is then accelerated to a preselected run speed and operated at the run speed until a signal is automatically generated for slowdown to permit safe tailoff. Product strip on the downcoiler has a reduced gauge according to the pre-established mill setup.

To provide improved productivity in an economic manner, an automatic slowdown control system **36** (FIG. 2) generates a mill slowdown signal at an operating time point which enables extended run speed operation to be achieved reliably from payoff reel to payoff reel of operation. The slowdown signal is applied to the master speed control **20** as shown in FIG. 1 to achieve mill deceleration. Optimum slowdown timing is more closely realized reliably and consistently without the use of an expensive programmed electronic computer.

The control system **36** can operate continuously but preferably is nonfunctioning until started by the limit switch **34** when the payoff coil diameter has dropped from the outer coil diameter D_{OC} to the builddown diameter D_S which preferably has a value greater by a predetermined amount than that value at which mill slowdown must be initiated in the worst expected payoff reel case. It is noteworthy at this point that a coil diameter limit switch similar to the limit switch **34** can of itself, as is well known, be used directly to initiate mill slowdown. However, the builddown diameter at which slowdown is to be initiated is relatively inaccurately detected by limit switch operation and further is fixed and not conveniently changeable from reel to reel of operation even though mill speed or payoff strip gauge changes would warrant a smaller builddown diameter value for the initiation of mill slowdown. In the present case, inaccuracy in detecting the coil builddown diameter D_S at which the limit switch is operated affects only the point in time at which the slowdown control **36** is initiated and in practice would therefore not affect the point in time at which the slowdown control **36** initiates mill slowdown.

When the start signal is generated by the limit switch **34**, a suitable electronic timer **38**, preferably in the form of a sampling timer, is sequenced to the "ON" state and in turn respective electronic gates **40** and **42** are turned on to allow pulses generated by the pulse generators **30** and **26** and detected by respective suitable detection circuits **44** and **46** to be gated to respective conventional 10 bit electronic counters **48** and **50**. The sampling timer **38** has an "ON-OFF" cycle primarily to allow reduced counter capacity for feedback pulse counting, i.e., the counters **48** and **50** may have a count capacity as small as 399 or less.

Generally, the timer "ON" time interval is adequate to allow sufficient pulse counting for comparison of the payoff reel and the deflector roll speeds. The timer "OFF" time interval is adequately small to assure the occurrence of a predetermined slowdown initiate roll deflector and payoff roll speed comparison condition during a timer "ON" time. The "ON" and "OFF" intervals are preferably made variable, and a typical timer "ON-OFF" cycle could comprise an "ON" interval of 0.5 second and an "OFF" interval of 0.1 second.

A conventional difference detector **52** compares the counter outputs, preferably not continuously and only after the end of each timer "ON" time interval, i.e., during each timer "OFF" time interval, as controlled by a timer signal indicated by the reference character **54**. When the timer **38** turns "OFF," the gates are operated to block pulses from the pulse generators **30** and **26** and reset signals are generated as indicated by the reference characters **56** and **58** to reset the counters **48** and **50** for the next "ON" interval. Prior to counter reset, the counts in the counters **48** and **50** are received by the difference detector **52** for comparison. If the counts have a predetermined relation to each other, such as when they are equal, the difference detector **52** generates a slowdown signal to decelerate the mill **10** as previously described. Timer operation is then terminated until the next payoff reel is put in place and run down to the limit switch coil diameter D_S.

Since the deflector roll diameter is a known value D_R, accurate pulse generator detection of the angular speed of the deflector roll **24** and the payoff reel **14** provides the information needed for accurate determination of the payoff coil builddown coil diameter. Assuming negligible slippage between the strip **12** and the roll **24**:

$$\text{Coil builddown diameter} = \frac{D_R \times \text{deflector roll angular speed}}{\text{payoff reel angular speed}}$$

In generating a slowdown signal, the difference detector **52** identifies a point in time at which a predetermined relation occurs between the coil builddown and deflector roll diameter and the corresponding relation between the reel and roll speeds. Preferably, the predetermined coil builddown and deflector roll diameter relation is one in which the coil builddown diameter value equals D_{ST} which is less than the control startup diameter D_S but nonetheless somewhat greater than that diameter value which assures safe tailoff for all expected payoff gauges and mill run speeds and particularly at the maximum expected mill run speed and payoff strip gauge conditions.

Once the safe tailoff coil builddown diameter D_{ST} value is selected, its ratio relation to the deflector roll diameter is fixed by the known roll diameter value D_R. As a consequence, the safe tailoff ratio between the payoff reel speed and the deflector roll speed is fixed. In order to make the counters **48** and **50** reflect the safe tailoff speed ratio at equal counts as preferred, the gearing **28** and **32** is suitably adjusted to take up any difference effect produced by a difference in the roll diameter and the safe tailoff coil builddown diameter. If a change is made in mandrel diameter, the selected safe tailoff coil builddown diameter and the safe tailoff speed ratio are accordingly modified.

A gauge/speed selector **54** is included in the control **36** to enable economic adjustment of the slowdown initiation point from the accurately detected safe tailoff builddown diameter value D_{ST} to a builddown diameter value D_{STO} which provides safe tailoff and more clearly approaches optimum productivity (i.e., more nearly approaches the builddown diameter corresponding to the latest allowable deceleration time point) according to the actual mill run speed and the gauge of the payoff strip in process. The selector **54** is manually set by the mill operator for each payoff reel as the reel is placed in the mill. For example, the selector can include a dial (not shown) which can be set in any of eight or any other preselected number of preselected positions such as follows:

TABLE OF SELECTOR ADJUSTMENTS

Dial setting	Offset count (increasing downward)	Strip gauge (increasing downward)	Mill run speed (decreasing downward)	Optimum coil builddown diameter for slowdown initiation (increasing downward)
1	C_1	G_1	S_1	D_1
2	C_2	G_2	S_2	D_2
3	C_3	G_3	S_3	D_3
4	C_4	G_4	S_4	D_4
5	C_5	G_5	S_5	D_5
6	C_6	G_6	S_6	D_6
7	C_7	G_7	S_7	D_7
8	C_8	G_8	S_8	D_8

The mill operator judges the dial setting which will most closely produce optimum operation on the basis of his experience and knowledge of the strip gauge and the mill run speed. In any event, operation of the control **36** is preferably made fail safe under all selector adjustment conditions, i.e. safe tailoff is assured even for the worst condition of heaviest gauge with the number 1 lightest gauge dial setting.

When the selector dial is manually set in any one position, suitable logic circuitry (not shown specifically) forming a part of the selector **54** is operated to generate a corresponding offset count entry in the payoff reel counter **48** at the start of each sample "ON" time as indicated by the reference character **57**. The gauge/speed selector **54** preferably also sets up the time cycle in the sampler timer **38** as indicated by the reference character **59**. Generally, it is preferred that the "OFF" time be retained at a constant value and the "ON" time be increased with increased strip gauge, i.e. the "ON" time is preferably made longer as the selector dial setting is increased from 1 to 8.

With the setting of the selector **54**, the difference detector **52** generates the slowdown signal during a sample "OFF" time if the pulse count form the deflector roll pulse generator **26** equals the pulse count from the payoff reel pulse generator **30** less the selector dial offset count registered during any single preceding sample "ON" time. Since the pulses produced by the generators **26** and **30** represent position increments, the counters **48** and **50** in effect operate as speed detectors and the difference detector **52** accordingly generates the slowdown signal when the ratio of the payoff reel and deflector roll speeds acquires the adjusted safe tailoff value.

In this manner, the slowdown signal is generated at a point in time which reliably results in extended run speed operation and improved mill productivity without requiring expensive electronic computation.

As an illustration of efficient control functioning, 0.125 inch gauge strip may correspond to G_8 in the above table and thus be processed at dial setting 8 and at mill run speed S_8. The offset count C_8 would be such that the slowdown signal would be generated to produce safe tailoff at a builddown diameter $D_{STO}=D_8$ which corresponds to 1.25 inches of wrapping thickness or about 10 wraps. For .008 inch guage strip, slowdown initiation at the same coil builddown diameter would occur safely but inefficiently at approximately 47 wraps. With adjustment of the selector **54** to the dial setting 1, the offset count C_1 would be such that the slowdown initiation signal would be generated to produce later and more efficient but nonetheless safe tailoff at a smaller coil diameter builddown value of $D_{STO}=D_1$ which corresponds to .16 inch of wrapping thickness or about 20 wraps.

The foregoing description has been presented only to illustrate the principles of the invention. Accordingly, it is desired that the invention not be limited by the embodiment described, but, rather, that it be accorded an interpretation consistent with the scope and spirit of its broad principles.

What is claimed is:

1. An automatic slowdown control for a rolling mill having a payoff reel and an entry deflector roll associated therewith, said control comprising signal generator means associated with the payoff reel, signal generator means associated with the entry deflector roll, means coupled to said payoff reel signal generator means for effectively detecting payoff reel speed, means coupled to said deflector roll signal generator means for effectively detecting the deflector roll speed, means for comparing respective outputs from said payoff reel and deflector roll speed detecting means to generate a mill slowdown signal when the speeds reach a predetermined relation, and an operator selector device including means for producing an offset output variably selectable from a range of values corresponding to differing combinations of mill operating speed and the gauge of strip being rolled, the offset output from said selector device coupled to at least one of said speed detecting means in order to control the point at which said comparing means generates the mill slowdown signal.

2. An automatic slowdown control as set forth in claim **1** wherein said payoff reel and entry roll deflector signal generating means are respective pulse generators respectively coupled to the payoff reel and the deflector roll, said speed detecting means are respective counters which respectively count the payoff reel and deflector roll generator pulses, said comparing means is a difference detector which compares the pulse counts in said counters, and the offset output from said selector device is an offset count applied to one of said counters.

3. An automatic slowdown control as set forth in claim **2** wherein said control includes a sampling timer, means are provided for initiating operation of said sampling timer when the payoff coil builddown diameter reaches a predetermined value, a gate is coupled between said payoff reel pulse generator and said payoff reel counter, another gate is coupled between said deflector roll pulse generator and said deflector roll counter, said timer operates said gates to couple the payoff reel pulses and the deflector roll pulses respectively to said counters during each timer sample ON time, said timer resetting said counters after sample ON time and initiating comparison operation of said difference detector near the beginning of each sample OFF time.

4. An automatic slowdown control as set forth in claim **3** wherein said selector device is coupled to said timer to control at least the length of the sample ON time in accordance with the aforementioned offset output.

5. An automatic slowdown control as set forth in claim **2** wherein the predetermined payoff reel and deflector roll speed relation corresponds to a predetermined coil builddown diameter value, said selector device is coupled to said payoff reel counter, and said selector device producing means provides a predetermined number of different offset counts which in effect provide for slowdown signal generation at respective different coil builddown diameter values all of which are less than the first mentioned coil builddown diameter value.

6. An automatic slowdown control as set forth in claim **5** wherein said selector device producing means is arranged to produce offset output values which assure fail safe operation including assurance of tailoff for any normally expected strip gauge and mill speed condition at any selector output setting.

7. An automatic slowdown control as set forth in claim **1** wherein the rolling mill is a nonreversing tandem cold steel strip reduction mill, the predetermined speed relation corresponds to a predetermined coil builddown diameter value, and said selector device producing means provides a predetermined number of different offset values which in effect provide for slowdown signal generation at respective different coil builddown diameter values all of which are less than the first mentioned coil builddown diameter value.

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