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STRIP REEL MOTOR DECELERATION DIGITAL CONTROL SYSTEM

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This invention relates to strip reeling control systems and has particular reference to a control system for reeling and unreeling strip material relative to a steel rolling mill.

In a system which is intended to wind a strip material on a reel and subsequently unwind the strip material without detaching the end of the material from the reel, it is evident that some control is advisable to prevent breakage of the strip or detachment of the strip from the reel when almost all of the material has been unreeled. For example, in reversing cold mills used for rolling steel, the steel is in strip form and is fed off one reel through the mill where it is reduced in section and then reeled on a second reel. This process may be reversed back and forth a number of times to produce the desired reduction in thickness of the strip material. It is desirable, however, that the ends of the strip, never be detached from the reel or permitted to pass through the rolls since this would entail rethreading of the strip through the rolls and slow down the operation. On the other hand it is desired that a maximum amount of the strip is fed through the rolls, leaving as little unwound on the reel as possible. This means that the operator must in some manner determine how much of the material is left on the reel from which the material is being fed, and stop the operation before the coil comes to the end of the strip. It is evident that if such control is exercised by the operator, it will necessitate slowing down the operation so that the operator can physically observe the amount of steel strip left on the one reel and approach the end of the strip gradually. If he approaches the end of the strip too gradually, this may cause variations in the thickness of the strip, since to some degree, the accuracy of rolling depends upon maintaining relatively constant speed of the strip material through the rolling mill. It will also slow down the operation since it will reduce the amount of steel going through the roll in a given period of time. On the other hand, if he does not slow down, he may either break the strip or leave an unwarranted amount of steel strip still wound on the reel; the latter obviously being wasteful.

It is therefore an object of this invention to provide an improved reel control system which will permit the rapid unwinding of the material from the reel and yet better control the operation to not permit the material to be completely removed from the reel but will leave a minimum amount of material on the reel.

It is a further object of this invention to provide an improved reel control system which will better permit the unreeling of the material at a more constant speed over a greater and the maximum possible portion of the strip.

In general, the foregoing objects are attained in accordance with our invention by producing a digital signal representative of the number of turns of material wound on the reel during both the winding process and during the unwinding process, producing a further signal in digital

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form representative of the linear velocity of the moving strip material, comparing these two digital signals in such a way that when the number of turns of material remaining on the reel in the unwinding process equals a number determined by the velocity of the strip a control signal is produced.

Considering now the figure, there is shown for illustration a portion of a steel rolling mill of the reversible type. A strip of steel 1 is passing through the work rolls 2 and thereby being reduced in thickness. The strip 1 is then wound on a reel 3 which is driven with a suitable driving motor means connected to the reel but not shown. Also connected to the reel is a shaft 4 which rotates with the reel, driving the gears in gear-box 5. The output from gear-box 5, still a rotational motion, is applied to pulse wheel 6. The gear-box contains a reduction gearing and the pulse wheel 6 therefore rotates at a slower speed than the reel. Associated with the pulse wheel 6 is a pulse circuit 7 which produces a pulse everytime a tooth of the wheel passes a prescribed point. Details of this portion of the circuit are not shown, since it is evident that various well known prior art devices and methods may be utilized to produce the pulses in the manner of the pulse wheel 6. The output from the pulse circuit is fed to a binary counter 8, which produces a binary representation of the number of rotations of the reel. This binary representation is fed to the coincidence circuit 9. The rolls 2 of the mill are driven by a motor 10 which is connected in a Ward Leonard circuit with generator 11. The field 12 of generator 11 is energized from the mill speed regulator 13. A controller potentiometer 14 coupled to the mill speed regulator controls the speed of motor 10 by the mill speed regulator and hence controls the speed of the work rolls 2 and also the velocity of strip 1.

A speed reference device 15 is co-ordinated with the speed regulator 14. This speed reference device comprises a series of contacts interconnected by resistive elements 17. Slider 18 is rotatable and contacts various of the contacts 16 depending upon the rotational position of the slider. Since its rotational position is coordinated with the controller 14 a desired resistive value is produced across terminals 19 representative of the speed of the driving motor 10 and hence representative of the linear velocity of strip 1. This resistive value is applied to the speed signal generator 20 and converted into a digital representation of the speed of strip 1.

This digital representation of the speed is fed to coincidence circuit 9. Coincidence circuit 9 is so arranged that when the digital input from the binary counter 8 and from the speed signal generator 20 are the same, a signal is produced on leads 21 which is applied to the control signal generator 22. It may also be arranged that when the digital input from binary counter 8 attains a certain given minimum value a further signal is generated by the coincidence circuit which produces an output on lead 23. The coincidence circuit 9 per se and its operation in this regard are conventional and known in the prior art. A switching signal is applied to terminal 24 which permits or inhibits an output from the control signal generator in accordance with the operative direction of the work rolls 2. This output from the control signal generator 22, is applied to lead 25 and thence to the mill speed regulator 13.

The operation of the system may be described as follows: Assume that the strip 1 is being fed from the work rolls in a direction toward and onto the reel 3. At the

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beginning of the operation after the strip has been threaded and connected to reel 3, the binary counter is zeroed. Thereafter as reel 3 is driven to wind strip 1 around it, the pulse wheel produces a series of pulses in accordance with the number of turns of strip that are wound on reel 3. These pulses are then converted and totaled by the binary counter 8 into additional representation of the number of turns of strip on reel 3.

Let us now assume that as much strip as may be permitted, has been passed through the work rolls and wound onto the reel 3. The binary counter 8 then contains a binary representation of a total number of turns on the reel 3. If the reel 3 is now reversed, the pulse circuit 7 produces a series of pulses which cause the binary counter to count down due to the reversal switching signal from the terminal 34. At the same time a speed signal is being produced in the speed signal generator 20 which is also applied to the coincidence circuit 9. This speed signal, while representative of the speed of the strip, also is a representation of the number of turns which must necessarily remain on the reel if the work rolls are to be brought to a standstill, in accordance with a specific rate of deceleration, without pulling the last turn off the reel. This should be readily apparent, since the time required for slowdown of the reel 3 at a given rate of deceleration is a function of both the speed of the reel in revolutions per minute and hence the speed of the strip 1 and also the number of turns of strip on the reel 3. It will be seen then, that if the binary counter indicates that a predetermined and specific number of turns remain on the reel and that this number of turns is the same as and correlated with the number of turns indicated by the speed signal generator, the coincidence of these two numbers indicate that the desired time has occurred for the mill speed regulator to commence deceleration of the mill. This desired coincidence of the two numbers is detected by the coincidence circuit and produces a signal on conductor 21, which in turn produces a signal in the control signal generator 22 which is fed to the mill speed regulator 13 and causes mill speed regulator to commence deceleration of the mill with a predetermined pattern. By proper selection in advance of the pattern and characteristic of the mill speed regulator and also of the output of the speed signal generator, it is evident that the mill can be repeatedly and effectively brought to a rapid halt with the desired minimum amount of strip remaining on reel 3.

If desired it is also possible to include in the coincidence circuit a signal generating circuit which indicates the point at which the output from the binary counter 8 contains a certain minimum output for example: corresponding to two turns of strip remaining on reel 3. At this point when there are only two turns of material left on the reel, a further signal may be produced by the control signal generator 22 and fed to the mill speed regulator to ensure that the mill drive stops at a specific point to prohibit the otherwise possible breaking of the strip 1.

It will be evident that a corresponding control system circuit is required for the other reel portion of the reversing mill which is winding while the illustrated portion is unwinding and vice versa.

The preceding operation in which reel 3 is unwinding strip will correspond in time with the time period in which the corresponding reel on the other side of the work rolls 2 is reeling the strip 1 and counting the number of turns on that corresponding reel, in preparation for the stopping of the corresponding reel not illustrated when the operation is reversed. It will also be evident that coincidence between the stored strip turns count and the signal produced by the speed signal generator will occur on the winding as well as on the unwinding cycle of each reel. Provision must therefore be made to control and inhibit the operation of the control signal generator 22, during the winding of the strip on reel 3. To this end a special signal is applied to terminal 24 from a strip direction

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signal device 26. This signal is generated only during the winding period of reel 3. It will be evident that this signal can be generated by any well known means such as a suitable strip direction sensing wheel 27 coupled to the direction signal device 26. There will be in the complete mill system, certain equipment required to cause a reversing of the mill and it will therefore be convenient if so desired to obtain from this equipment a signal indicative of the direction of strip movement. This signal may also be utilized to control the binary counter operation so that it will count up during the winding process and count down during the unwinding process. To this end, terminal 24 is also connected to the binary counter as shown.

It will be appreciated that while specific apparatus is shown for performing certain functions such as producing speed reference signals, pulse signals, and the like, numerous alternatives will be evident to those skilled in the art, for example, it is conceivable that the speed signal generator 20 be energized from a signal obtained directly from the mill speed regulator or even directly from the strip. It is also conceivable that some alternate form of pulse producing mechanism could be used to indicate the rotations of the reel 3 and hence strip turns thereon. Specific circuit diagrams of the various elements in the system have not been shown since suitable circuits are conventional per se and very well known in the art. For example, reversible binary counters energized by applied input pulses or binary number generators energized by an input analog voltage, current or resistive values, coincidence circuits and the like are very well known as individual circuit elements suitable for use in the illustrated control system.

We claim as our invention:

1. A strip reel control system for a strip winding reel operative with a roll of strip material and comprising first signal means to produce first electrical signal pulses and including a pulse counter for providing a stored signal representative of the number of turns of strip wound on said reel, second signal means to generate a second electrical signal representative of the velocity of the strip, signal comparison means to compare said stored signal and said second signal and operative to produce a further signal representative of a predetermined relationship between said stored signal and second signal when the number of turns of strip wound on said reel is substantially equal to the number of turns desired to effect a predetermined deceleration of said reel to thereafter leave a predetermined number of turns of strip on said reel, and reel control means to utilize said further signal to control the deceleration of the strip, wherein said pulse counter of the first signal means additively collects said first signal pulses when said strip material is wound on the reel and subtractively discards said first signal pulses when the material is unwound from said reel.

2. A strip reel control system for a strip winding reel operatively with a roll of strip material and comprising first signal means to produce first electrical signal pulses and including a pulse counter for providing a stored signal representative of the number of turns of strip wound on said reel, second signal means to generate a second electrical signal representative of the velocity of the strip, signal comparison means to compare said stored signal and said second signal and operative to produce a further signal representative of a predetermined relationship between said stored signal and second signal when the number of turns of strip wound on said reel is substantially equal to the number of turns desired to effect a predetermined deceleration of said reel to thereafter leave a predetermined number of turns of strip on said reel, and reel control means to utilize said further signal to control the deceleration of the strip, including third signal means to generate a third signal representative of a predetermined number of turns of strip material on said reel, with said

reel control means being operative to utilize said third signal to control the stopping of the reel.

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