

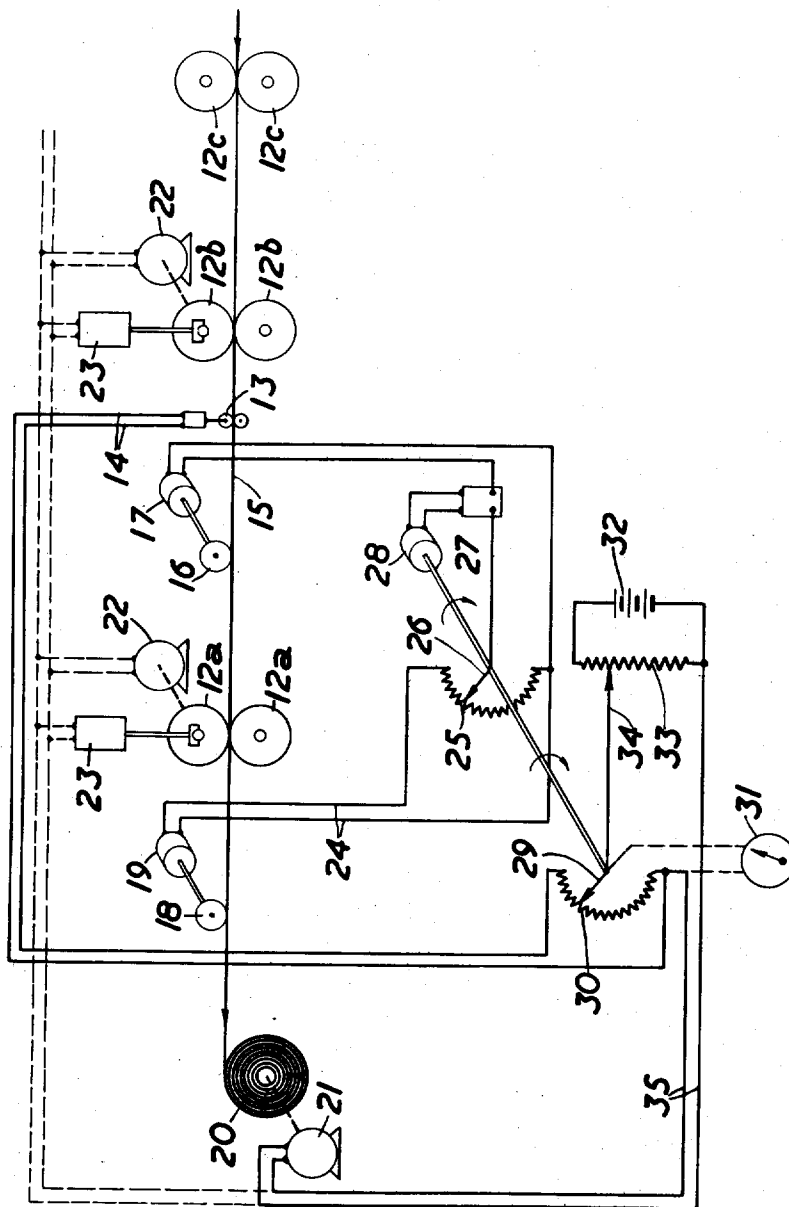
Oct. 31, 1961

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Re. 25,075

ROLLING MILLS

Original Filed Jan. 25, 1955



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25,075

ROLLING MILLS

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Original No. 2,851,911, dated Sept. 16, 1958, Ser. No.
483,910, Jan. 25, 1955. Application for reissue Sept.
13, 1960, Ser. No. 55,815

Claims priority, application Great Britain Jan. 26, 1954
10 Claims. (Cl. 80-32)

Matter enclosed in heavy brackets [] appears in the
original patent but forms no part of this reissue specifi-
cation; matter printed in italics indicates the additions
made by reissue.

This invention relates to rolling mills, particularly for
steel. Rolling mills may be so arranged that the rolled
material is passing through a number of individual roll
stands at the same time. The continuous strip mill in
which the strip passes simultaneously through several
stands arranged in tandem is a well known example.
One of the objects of continuous rolling is to produce
long lengths of material having a desired cross-section
which varies as little as possible from one end to the
other. In a tandem strip mill changes in thickness may
occur as the result of disturbances in one or more of
the roll stands and it is desirable that these should be
corrected before the material issues from the last stand.
An object of this invention is to provide a method for
achieving this.

It is a characteristic of continuous mills that, unless
the material is allowed to accumulate between the stands
or is subjected to increasing and finally destructive tensile
stresses, the rate in volume units per second at which
material leaves one stand must equal the rate at which
it enters the next. It is also well known that in the roll-
ing of metals their density is not appreciably affected
by the deformation they receive. It is therefore possi-
ble to state that in a continuous mill where the material
neither accumulates nor is subjected to increasing tension
between the stands, the volume of material passing any
point in a given time is the same for all points through-
out the system. In the special case of a wide strip mill
where the width of the strip is not affected by rolling,
the thickness of the strip multiplied by the speed of the
strip will yield the same product at any point. This
product is the output of the mill.

The present invention employs the above features to
provide apparatus for measuring the issuing thickness
of strip from a rolling mill and for controlling the mill
to maintain a strip thickness at a desired value. Thus,
according to the present invention, in a method of measur-
ing the thickness of strip leaving a rolling mill, the out-
going thickness is derived from measurement of the speed
and thickness of the strip prior to passage out of the
mill and of the speed of the strip leaving the mill. For
a multi-stand mill, the speed and thickness is measured
between any two adjacent stands so that the output can
be derived; the output is then compounded with the
speed of the strip leaving the mill to give an indication
of the issuing strip thickness.

The invention includes apparatus for maintaining at
the desired value the thickness of wide strip leaving a
multi-stand rolling mill comprising means for producing
signals in accordance with the speed (v_1) and the thick-
ness (h_1) of the strip between two adjacent stands of
the mill, means for producing a signal in accordance
with the speed of the strip (v_2) leaving the mill, means
for compounding the said signals to produce a resultant
signal, representing the issuing thickness, in accordance
with

$$\frac{v_1 h_1}{v_2}$$

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and means controlled by the resultant signal for main-
taining the issuing thickness at the desired value.

The invention will be more readily understood by way
of example from the following description of a continu-
ous multi-stand steel rolling mill, reference being made to
the accompanying drawing which is a schematic repre-
sentation of the mill.

In the drawing, the rolls of the stands of the mill are
indicated at 12a, 12b, 12c, etc., it being understood that
the mill may have as many stands as may be desirable.
Between any two adjacent stands, there are located a
micrometer 13 which gives an electrical signal on the
output lines 14 in accordance with the thickness of the
strip 15 between those stands, and a device for giving
an electric signal proportional to the linear speed of the
strip as it passes between the stands. This device con-
sists of a disc 16 mounted on the rotor of a tachometric
generator 17, the arrangement being such that the plane
of the disc 16 is aligned with the direction of motion
of the strip 15 and the disc rotates at the same peripheral
speed as the strip. The micrometer 13 and the device
16, 17 are shown between the last two stands of the mill,
but it will be understood that they may be located be-
tween any two other stands.

A second device for measuring the speed of the strip
is located at the issuing side of the last roller stand 12a.
This device is similar to the device 16, 17 and comprises
a disc 18 in frictional contact with the strip and carried
on the motor of a tachometric generator 19.

The mill is provided with the customary reeling drum
20 for the strip, the reeler motor 21 and a driving motor
22 and screw-down motor 23 for each of the roller stands;
the driving motor 22 drives the rolls, whereas the screw-
down motor 23 causes adjustment in the initial setting
of the work rolls 12 in relation to one another.

The output of generator 19 appearing at lines 24 is
applied across an arcuate potentiometer 25. The signal
appearing between the slider 26 of the potentiometer and
one end of the potentiometer is applied in series opposi-
tion to the output from generator 17 to the input of a
high gain amplifier 27, the output from which is con-
nected to a light motor 28. The rotor shaft of motor
28 carries the slider 26 of potentiometer 25 and also
the slider 29 of a second arcuate potentiometer 30. The
electric signal appearing on the output lines 14 of mi-
crometer 13 is applied across potentiometer 30 and the
signal appearing on the slider 29 and one end of the
potentiometer is proportional to the outgoing thickness
of the strip and an indication of that thickness can be
given by connecting the two points to a meter 31.

Alternatively, a signal may be derived proportional to
the deviation of the issuing thickness from a given value
by connecting slider 29 and one side of the potentiom-
eter 30 in series opposition to a source of voltage in-
dicated in the drawing as a battery 32 connected across
the potentiometer 33. The slider arm 29 is connected
to the slider 34 of potentiometer 33 and the difference
voltage appears on lines 35.

In order to provide an automatic control system for
maintaining the issuing thickness of the strip substan-
tially at a given value determined by the setting of the
potentiometer 33, the signal appearing on lines 35 may
be applied to the reeler motor 21, as shown, or alterna-
tively to any of the screw-down motors 23 of the roll
stands or to any of the drive motors 22, as indicated in
chain line.

The operation of the system is as follows. If the speed
and thickness of the strip between stands 12a and 12b are
 v_1 , h_1 and the speed and thickness of the strip, as it leaves
the mill, are v_2 and h_2 , then the voltage applied across
potentiometer 25 is V_1 proportional to v_1 and the voltage
appearing between slider arm 26 and one end of the

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potentiometer is kV_2 where k is determined by the position of the slider on the potentiometer. The voltage applied to the input of amplifier 27 is therefore proportional to $(V_1 - kV_2)$ where V_1 is proportional to v_1 and as the gain of the amplifier 27 is large the angular position of rotor shaft of motor 28 will be

$$\frac{v_1}{v_2} = \frac{V_1}{V_2}$$

since at balance the input to the amplifier will be very nearly zero. Thus, as the voltage applied across potentiometer 30 is proportional to h_1 , the signal appearing at the slider 29 and one end of the potentiometer 30 is proportional to

$$h_1 \frac{v_1}{v_2}$$

and because the output for wide strip is constant along the whole length of the strip and therefore $h_1 v_1 = h_2 v_2$, this signal is proportional to h_2 , the issuing thickness of the strip and the meter 31 will indicate that thickness.

When used, the potentiometer 33 applies a constant voltage h in opposition to the voltage from potentiometer 30 and the signal appearing at output lines 35 is therefore $h_2 - h$, the deviation of the thickness from a given value. When this voltage is applied to control any of motors 21, 22 or 23, the rolling mill will operate to maintain the output signal on lines 35 zero or, in other words, the issuing thickness of the strip at the desired value h , determined by the position of the slider 34.

As will be appreciated, the system illustrated in the accompanying drawing enables the thickness or gauge of the strip leaving the mill to be measured indirectly with the attendant advantage that the strip thickness is measured as it leaves the last roll stand and not at some distance from that stand. This advantage is of particular value when the system is used for automatic control of the mill as it enables irregularities in the thickness to be compensated immediately instead of after a time lag.

In another embodiment, the micrometer and the two speedometers are employed as before, but in this case percentage variations are measured. The signals from the micrometer and speedometer located between the stands are compounded to give a resultant signal equal to the output $(v_1 \times h_1)$. From this resultant signal is obtained a signal proportional to the percentage variation of the output from a given value, the given value corresponding to a desired thickness. Similarly, the signal from the speedometer measuring the speed of the issuing strip is modified to give a signal proportional to the percentage variation in the issuing strip [thickness] speed from the given value, again corresponding to the desired thickness. The two percentage signals are applied in series opposition to give a difference signal proportional to the percentage variation of the issuing thickness of the strip from the desired value. This signal can be applied to the reeling motor or to the screw-down or driving motors of the stands to compensate automatically for variations in the thickness and to maintain that variation zero.

As a result of the adjustments in accordance with the percentage variation signal, there will occur changes in the tensions in the strip between the stands, which will bring the whole system into a new equilibrium. Changes in the thickness arising anywhere in the mill will be offset by the effects of these changes in tension on the strip thickness in such a way that there will be no resultant change in the thickness of the strip as it leaves the final stand.

What is claimed, is:

1. In a rolling mill having a motor operated final stand and at least one motor operated preliminary stand, manually adjustable means for [controlling] setting the thickness of the strip issuing from said final stand, first variable signal generating means responsive to the velocity of a partially finished strip supplied to said final stand,

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second variable signal generating means responsive to the thickness of said strip supplied to said final stand, third variable signal generating means responsive to the velocity of the strip issuing from said final stand, and a signal correlating means responsive to the setting of said manually adjustable means and all of said signal generating means, said correlating means [varying the speed of operation of said final stand motor so as to maintain the product of the thickness and velocity of said issuing strip constant to the product of the thickness and velocity of said supplied strip.] controlling said mill to adjust the thickness of the strip issuing from said final stand substantially to the value set by said manually adjustable means.

15 2. A rolling mill as set forth in claim 1, wherein said signal correlating means comprises a motor having a rotor, the position of said rotor being adjustable in response to changes in the [difference between] quotient of the signals produced by said first and third signal generating means, and a potentiometer having a slider coupled to said rotor, said second signal generating means comprising a source of voltage across said potentiometer, [the difference in the signals generated by said first and third signal generating means being detectable across said slider and one terminal of said potentiometer.] the voltage drop across one terminal and said slider being applied in opposition to the setting of said manually adjustable means for controlling said mill.

3. A rolling mill as set forth in claim 2, further comprising a second potentiometer, said [first] third signal generating means being connected across said second potentiometer, said second potentiometer having a slider connected to said rotor and a high gain amplifier connected [across one terminal and] to said slider of said second potentiometer, the voltage drop across one terminal and said slider of said second potentiometer being applied [to the input of said high gain amplifier for controlling said final stand motor.] in opposition to the signal from said first generating means to the input of said high gain amplifier, and the output of said amplifier controlling said motor having said rotor.

4. In a rolling mill having a motor operated final stand, at least one motor operated preliminary stand, and reeling means for drawing strip through said stands, manually adjustable means for setting the value desired for the thickness of the strip issuing from said final stand, first variable signal generating means responsive to the velocity of a strip supplied to said final stand, second variable signal generating means responsive to the thickness of said strip supplied to said final stand, third variable signal generating means responsive to the velocity of the strip issuing from said final stand, and a signal correlating means responsive to the setting of said manually adjustable means and all of said signal generating means, said correlating means controlling said reeling means to control the thickness of strip issuing from said final stand substantially to the value set by said manually adjustable means.

5. In a rolling mill having a motor operated final stand, at least one motor operated preliminary stand, reeling means for drawing strip through said stands, and means for controlling the separation of the rolls of at least one of said stands, manually adjustable means for setting the value desired for the thickness of strip issuing from said final stand, first variable signal generating means responsive to the velocity of a strip supplied to said final stand, second variable signal generating means responsive to the thickness of said strip supplied to said final stand, third variable signal generating means responsive to the velocity of the strip issuing from said final stand, and a signal correlating means responsive to the setting of said manually adjustable means and all of said signal generating means, said correlating means controlling said controlling means to adjust the thickness of the strip issuing from said

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final stand to the value set by said manually adjustable means.

6. In a rolling mill having a motor operated final stand, at least one motor operated preliminary stand and reeling means for drawing strip through said stands, manually adjustable means for setting the value desired for the thickness of strip issuing from said final stand, first variable signal generating means responsive to the velocity of a strip supplied to said final stand, second variable signal generating means responsive to the thickness of said strip supplied to said final stand, third variable signal generating means responsive to the velocity of the strip issuing from said final stand, and signal correlating means responsive to the setting of said manually adjustable means and all said signal generating means, said correlating means automatically varying the speed of operation of one of the motors of one of said stands to adjust the thickness of the strip issuing from said final stand to the value set by said manually adjustable means.

7. In a rolling mill having at least one motor operated stand, an automatic control system for maintaining the thickness of the strip at a required value comprising means for measuring the thickness of the strip at the entry side of the stand and for generating a first signal representing that thickness, means for generating a second signal representing the quotient of the velocities of the strip at the two sides of the stand, correlating means controlled by the first and second signals for generating an error signal indicative of the departure from a required value of the thickness of the strip leaving the stand, and control means controlled by the error signal for controlling the thickness of the strip leaving the stand.

8. In a rolling mill having at least one motor operated stand, reeling means for drawing strip through said stand, and means for controlling the separation of the rolls of said stand, manually adjustable means for setting the value desired for the thickness of the strip issuing from the stand, first signal generating means responsive to the thickness of the strip supplied to said stand for generating a first signal representing that thickness, second generating means for generating a second signal representing the quotient of the velocities of the strip at the two sides of the stand, correlating means responsive to said manually adjustable means and said first and second signals for generating an error signal indicative of the departure from said desired value of the thickness of the strip leaving said stand, and means for applying said error signal to said

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means controlling the separation of said rolls, to maintain said error signal substantially zero.

9. In a rolling mill having at least one motor operated stand, reeling means for drawing strip through said stand and control means for controlling the reeling means, manually adjustable means for setting the value desired for the thickness of the strip issuing from said stand, first generating means responsive to the thickness of the strip supplied to said stand for generating a first signal representing that thickness, second generating means for generating a second signal representing the quotient of the velocities of the strip at the two sides of the stand, correlating means responsive to said manually adjustable means and said first and second signals for generating an error signal indicative of the departure from said desired value of the thickness of the strip leaving the stand, and means for applying said error signal to said control means to maintain said error signal substantially zero.

10. In a rolling mill having at least one motor operated stand and means for drawing strip through said stand, first variable signal generating means responsive to the velocity of strip supplied to said stand, second variable signal generating means responsive to the thickness of said strip supplied to said stand, third variable signal generating means responsive to the velocity of the strip issuing from the mill, correlating means responsive to all said generating means for generating an error signal indicative of the departure from a required value of the thickness of the strip issuing from said mill control means for controlling the thickness of the strip issuing from said mill, and means applying said error signal to said control means.

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