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[31] **43/48458**

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[54] **APPARATUS FOR METHOD FOR DETERMINING
THE DEGREE OF ELONGATION OF METAL
STRIPS**
6 Claims, 7 Drawing Figs.

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517 AV

ABSTRACT: An apparatus to perform the method which comprises the steps of forcibly applying vibrations to a metal strip to generate standing wave vibrations at a prescribed wavelength, and measuring the amplitude of the standing wave vibration, thereby defining the degree of elongation of said strip from the values of the amplitude and the wavelength.

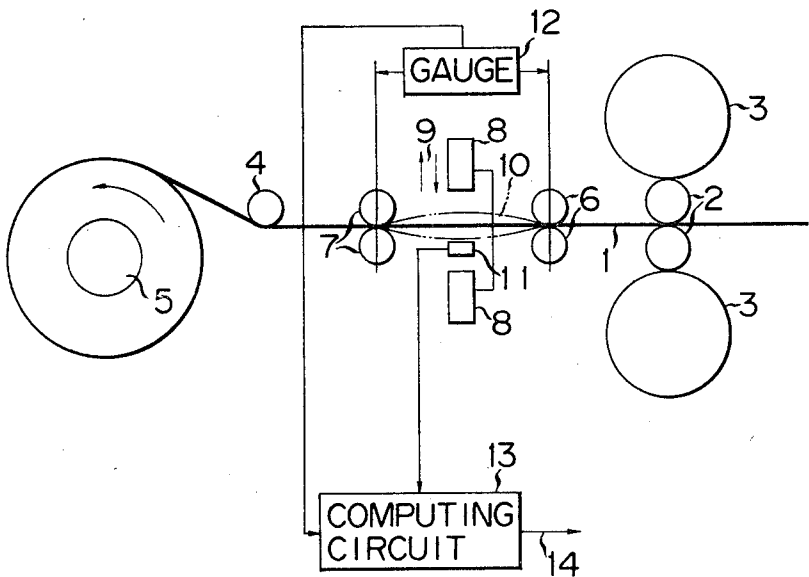


FIG. 1A

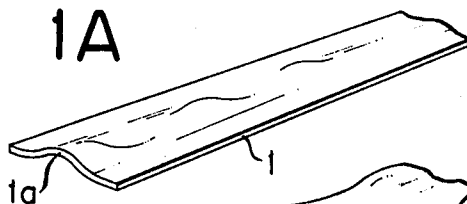


FIG. 1B



FIG. 2

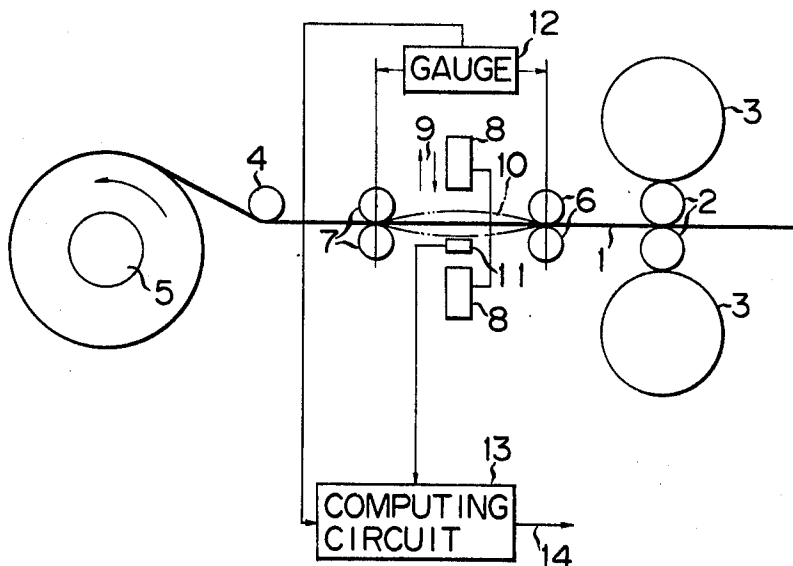
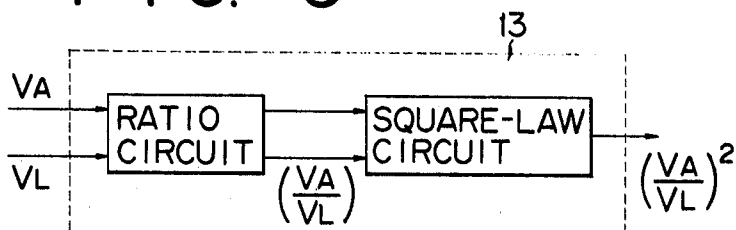


FIG. 5



APPARATUS FOR METHOD FOR DETERMINING THE DEGREE OF ELONGATION OF METAL STRIPS

The present invention relates to an apparatus for determining the degree of elongation of metal strips.

The rolling of metal strips so as to allow them to have an excellent flatness and desired shape demands that the strip be elongated uniformly. Local variations in the degree of elongation will lead to the occurrence of undulations on the surface of a rolled metal strip. These undulations may broadly be classified into those appearing along the central part of the strip extending in a direction perpendicular to the transverse direction of the strip, i.e., the direction in which it is rolled (hereinafter referred to as the "central undulations") and those presented on the edge or edges of the strip (hereinafter referred to as the "edge undulations").

To prevent the occurrence of central or edge undulations, there are used a pair of crown rolls in rolling metal strips. The term "crown roll", as used herein, denotes the type, the central portion of which generally projects outward, as well as a simple cylindrical type. To avoid the generation of edge undulations, the crown roll is designed to receive an external load to be so curved as to allow a greater pressure to be applied to the central part of a rolled strip, and to eliminate the appearance of central undulations, said roll also receives such an external load to be so curved as to allow a greater pressure to be applied to the edge portion of a rolled strip. Accordingly, the occurrence of edge or central undulations can be restricted according to the manner in which the external load is impressed. To control the application of said load, namely, the operation of the crown roll, it is necessary to measure in advance the degree of deformation of a rolled strip. However, such measurement presents considerable difficulties for the following two reasons. First, the strip travels at a high speed, so that a measuring method involving a mechanical contact with the surface of a strip is impracticable. Secondly, a metal strip is subject to a fairly great tensile force at the time of rolling, so that the amplitude of the wave form of edge and central undulations is smaller than when the strip is relieved of such tensile force.

It is accordingly the object of the present invention to provide an apparatus for determining the degree of elongation of a rolled metal strip without directly contacting it.

In brief, the present invention consists in forcibly applying at the outlet of work rolls vibrations like those having a standing wave of a prescribed wavelength to a travelling metal strip and measuring the amplitude of these vibrations without touching the strip, thereby defining the degree of its elongation.

This invention can be more fully understood from the following detailed description when taken in connection with reference to the accompanying drawings, in which:

FIGS. 1A and 1B are schematic perspective views of the typical examples of the deformation of a rolled metal strip;

FIG. 2 is a diagrammatic representation of an apparatus according to an embodiment of the present invention;

FIG. 3 is an enlarged diagram of the main part of the embodiment of FIG. 2;

FIG. 4 is a schematic diagram of a means for detecting the amplitude of vibrations as employed in the embodiment of FIG. 2;

FIG. 5 is a block diagram showing a circuit for determining the degree of elongation; and

FIG. 6 is a schematic diagram of an apparatus according to another embodiment of the invention.

Before describing an embodiment of the present invention, let us refer to FIG. 1 in which the aforesaid central and edge undulations of the strip 1 are denoted by 1a and 1b respectively.

There will now be described an embodiment of the present invention by reference to FIGS. 2 to 4, in which the same parts are denoted by the same numerals. Referring to FIG. 2, a

metal strip 1 is rolled by a pair of work rolls 2 supported by a pair of backup rolls 3, and wound about a takeup reel 5 in the direction of an arrow by the medium of a guide roll 4. Between the work rolls 2 and guide roll 4 are disposed two pair of keep rolls 6 and 7 at a prescribed space L. These keep rolls 6 and 7 so act as to restrict the scope of the vibrations of the strip 1 occurring in the direction of its thickness.

Numeral 8 represents vibration means disposed on the opposite sides of the strip 1. These vibration means 8 are operated by turns to vibrate the strip 1 at a prescribed frequency in the direction of the arrow 9 so as to forcibly generate vibration waves like standing waves (hereinafter referring to as the "standing wave"). The vibration means 8 may consist of those which eject, for example, the fluid to the strip 1 by turns, or those which alternately apply an electromagnetic force to the strip 1 if it is made of a magnetizable material, and can be easily prepared by the known techniques. Numeral 11 is a detector for detecting the amplitude A of the standing wave 10. Numeral 12 is a gauge for measuring the distance between the aforesaid two pairs of keep rolls 6 and 7, which may be formed of a potentiometer interlocking with, for example, said keep rolls 6 and 7. Signals representing the measured distance L and those issued from the detector 11 are conducted to a circuit 13 for computing the degree of elongation of a metal strip. Numeral 14 denotes signals fed back to a means involved in a roll apparatus for controlling the flatness of a strip known to those skilled in the art which is formed of a screwdown control device, crown control device and etc.

The foregoing description including the related drawing relates by way of convenience to the case where a single detector 11 was employed. Generally, however, there are arranged a plurality of detectors in the transverse direction of a metal strip, and also a plurality of calculation circuits 14 in corresponding relationship thereto.

There will now be described the operation of the apparatus of the present invention and the principle of determining the degree of elongation of a rolled metal strip. When the strip travels quickly, vibrations occurring in the direction of its thickness present a complicated state in which vibrations having progressive waves like those presented by edge and central undulations resulting from the rolling of said strip overlap the intrinsic vibrations defined by the tensile force acting on the strip 1 and the interval between the keep rolls 6 and 7. Of these vibrations, those represented by the edge and central undulations are the so-called buckling phenomenon, so that when a metal strip travels quickly, they irregularly vary in wavelength and phase and present complicated waveforms. However, if vibrations are forcibly applied, as in the method of the present invention, to a metal strip held by keep means disposed at a prescribed space L, there can be obtained a standing wave in which the half wavelength is equal to L and the function of waveforms is substantially fixed. Accordingly, determination of the amplitude of said standing wave enables the degree of elongation of those parts of a strip corresponding to the standing wave to be easily computed.

Referring to FIG. 3, the longitudinal direction of the strip 1 is designated as an x axis, the direction thereof perpendicular to said longitudinal direction and extending toward the vibration means 8 as a y axis and the point at which the x and y axes intersect each other as the base point O. Then the standing wave 10 having a maximum amplitude A may be approximately expressed by equation I below.

$$y = A \sin \pi/L \cdot x \quad I$$

(In this case, the amplitude A is far smaller than the half wavelength L, so that approximation using a sine wave does not practically present any difficulties.) The length L' of that portion of a metal strip in which there are generated standing waves whose amplitude is A and whose half wavelength is L may be expressed by equation II below

$$L' = \int_0^L \sqrt{1 + \left(\frac{dy}{dx}\right)^2} dx = L \left[1 + \left(\frac{\pi A}{L}\right)^2 \right] \quad II$$

With the distance L between the keep means or rolls taken as the base, the degree e of elongation of a metal strip may be determined from equation III below.

$$e = \frac{L' - L}{L} = \left(\frac{\pi A}{L} \right)^2 \quad \text{III}$$

This degree e of elongation can be calculated immediately by the computation circuit 13. For example, the circuit 13 for determining the degree of elongation e as shown in FIG. 5 comprises a ratio circuit which is impressed with the output voltage V_L ($V_L = K_L \cdot L$ where K_L denotes the constant of a unit volt/cm.) of the gauge for distance and the output voltage V_A ($V_A = K_A \cdot A$ where K_A denotes the constant of a unit volt/cm.) of the detector 11 and gives forth an output corresponding to the ratio between these input voltages (V_A/V_L) and a square-law circuit which is cascade connected to the first mentioned circuit to square outputs therefrom. If the degree e of elongation is determined at a plurality of points located in the transverse direction of a metal strip, and a load to be applied to a means for controlling the flatness of the surface of the metal strip, for example, a pair of crown rolls, are adjusted in accordance with the distribution pattern of the determined degrees of elongation at said points thereby to cause said rolls to be curved in a desired manner, then it will be possible to control the shape or flatness of the rolled metal strip.

The amplitude A of the standing wave can be detected, for example, optically. There will now be described an example of such detection by reference to FIG. 4. In this figure, the travelling direction of a metal strip 1 is designated as an x axis, the direction of its thickness as a y axis, its transverse direction as z axis and the point at which the three axes intersect each other as the base point O . The standing wave cut by the $x-y$ plane is indicated by the aforementioned equation I. Now let it be assumed that light beams 15 are projected from point $P(X, H, -a)$ to point $R(X, O, O)$. Then the reflected light beams 15' will display different distances $\pm d$ from point $Q(X, H, a)$. In case of $H \gg A$, said distance d may be expressed as follows:

$$d = \frac{2A\pi}{L} H \cos \frac{\pi}{L} X \quad \text{IV}$$

If, the distance d is determined as a difference in the amounts of light beams detected by a pair of photoelectric detectors S_1 and S_2 divided by the $y-z$ plane with x taken as equal to X , then the amplitude A of the related standing wave can be easily defined from equation IV above.

The standing wave may be generated, as illustrated in FIG. 6, by arranging two rolls 16 and 16' acting as guide rolls at an interval of L instead of using the aforementioned keep rolls 6 and 7. Further the work rolls 2 may be substituted for one of said rolls 16 and 16'. It will also be apparent that means for generating the standing wave and means for determining the amplitude thereof are not limited to those used in the aforementioned embodiments.

What we claim is:

1. An apparatus for determining the degree of elongation of metal strips before they are wound about a takeup device after they are rolled by work rolls which comprises means for forcibly applying between the work rolls and takeup device vibrations having a prescribed frequency to a travelling metal strip in the direction of its thickness, means for limiting the scope of vibrations generated by said vibration means to the prescribed portion of the metal strip in its longitudinal direction, so as to cause vibrations substantially to display a standing wave having a prescribed wavelength, means for determining the amplitude of the standing wave vibrations in the metal strip, and means for computing the degree of elongation of the metal strip upon receipt of signals representing said amplitude issued from the amplitude determining means.

2. An apparatus according to claim 1 wherein the means for forcibly applying vibrations consists of a pair of ejecting devices disposed on the opposite sides of the metal strip in a manner to face each other and so designed as to eject fluid by turns to the metal strip.

3. An apparatus according to claim 1 wherein the means for forcibly applying vibrations consists of a pair of electromagnetic devices positioned on the opposite sides of the metal strip in a manner to face each other and so designed as to apply an electromagnetic force to the metal strip.

4. An apparatus according to claim 1 wherein the means for limiting the scope of vibrations consists of two pairs of rolls arranged at a prescribed interval in a manner to hold the metal strip therebetween.

5. An apparatus according to claim 1 wherein said amplitude determining means comprises a plurality of detectors in the transverse direction of the strip.

6. An apparatus according to claim 1 wherein said amplitude determining means consists of a light source to project light beams to the strip and a pair of photoelectric converters arranged to receive the light beams reflected from said strip to generate an electrical signal.

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