(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 151 675 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 84107573.2

(22) Date of filing: 29.04.81

(51) Int. Cl.[4]: B 21 B 37/02

(43) Date of publication of application: 21.08.85 Bulletin 85/34

(84) Designated Contracting States: DE FR GB

(60) Publication number of the earlier application in accordance with Art. 76 EPC: 0 063 633

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(54) Method of automatically controlling the rate of reduction in a rolling mill.

(57) The invention describes a method for automatically controlling the rate of reduction suitable for ARC mode of the method for automatically controlling the strip thickness, the rate of reduction is controlled such that an output thickness of the material is calculated from an actually measured input thickness of the material and the desired rate of reduction based on the principle of the constant mass-flow rate of the material being rolled an input thickness is estimated from the calculated output thickness, an input length and an output length and an error signal between the estimated input thickness and the actually measured input thickness is diminished to zero.

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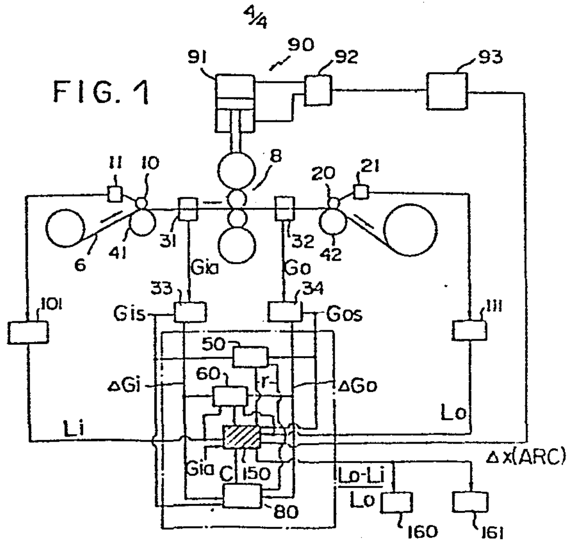
FIG. 1



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EP 314-411/lr

June 29 , 1984

A METHOD OF AUTOMATICALLY CONTROLLING THE RATE OF REDUCTION IN A ROLLING MILL

The invention relates to a method of automatically controlling the rate of reduction in a rolling mill for rolling a material being rolled at a predetermined rate of reduction.

In recent years necessity has been voiced for improved accuracies in plate thickness in the rolling of steel sheets by means of rolling mills, particularly in the cold rolling of thin steel sheets such as an electrical steel sheet and a stainless steel sheet by means of Sendzimir mills and consequently it is desired to improve the accuracy in strip thickness control.

As a method of controlling the strip thickness of a device therefore there have heretofore been employed automatic gauge control (for example see US-PS-42 44 025) for diminishing to zero the deviation in the output side strip thickness from a predetermined desired uniform gauge thickness and automatic reduction rate control (see US-PS-36 24 369).

The ARC contemplates to correct the input deviation by the value corresponding to the rate of reduction, whereby the output value of rate of reduction is low as compared with the aforesaid AGCs, so that the load of the screwdown system can be low, the responsibility enhanced and the stability improved.

A specific method of ARC, in which the rate of reduction is controlled at a predetermined value, is one in which the rate of reduction is detected to control the roll gap to become equal to the desired rate of reduction in the same manner as in the ordinary strip thickness control, in which the strip thickness of the output side of the mill is measured to control the rate of reduction.

As methods of measuring the rate of reduction in this case there have heretofore been known a method of measuring the rate of reduction by use of a strip thickness gauge, a method of measuring the percentage of elongation from the strip length or strip speed by use of deflectorodes, etc. With ARC by use of the former, the position, where the strip thickness gauge is provided is apart from the positions of work rolls, whereby a delay in time takes place due to the travel of the material therebetween, thus deteriorating the controllability. With ARC by use of the latter, errors occuring due to slip between the deflectorrolls and the steel sheet and the difference between the diameters of rolls hamper the accurate measurement of the percentage of elongation.

In addition another ARC contemplates to obtain a constant rate of reduction by rolling at a predetermined pressure by use of an accumulator and rolls being low in elasticity. However, particularly the mills having a multiroll arrangement have hysterisis due to friction and looseness thus presenting such a disadvantage that a constant rate of reduction is not easily obtainable. It is therefore the task of the present invention to provide a method of automatically controlling the rate of reduction in a rolling mill capable of carrying out rolling at a constant rate of reduction being stabilized with high accuracy. This task is solved by a method of automatically controlling the rate of reduction in a rolling mill for rolling a material being rolled at a predetermined rate of reduction, wherein the rate of reduction is controlled in such a manner, that an output thickness of the material being rolled is calculated from an actually measured input thickness of the material and a desired rate of reduction based on the principle of the constant massflow rate of the material being rolled, an input thickness is estimated from the output thickness thus calculated, an input length and an output length and the difference between the estimated input thickness and an actually measured input thickness can be diminished to zero.

With these features there is no delay in time due to the travel of the material and calculation includes the input thickness, so that satisfactory response to the input thickness can be obtained. According to preferred embodiment of the present invention said estimated input thickness is feedback corrected by a correction value obtained by adding an averaging difference between a calculated output thickness deviation and an actually measured thickness deviation of the material being rolled over a predetermined length of the material. With these features it is possible, to obviate the steady variations from the desired value in the rate of reduction due to errors in measurement of the strip length, changes in strip width or the like in the above mentioned methods of automatically controlling the rate of reduction.

Detailed description will herewith be given of the method of the present invention with reference to the drawings, in which Fig. 1 is a block diagram, showing a reduction control system, in which the method of automatically controlling the rate of reduction according to the present invention is applied to a reversing mill, Fig. 2 is a diagram showing an example of the changes in thickness deviation in the use of the inventive method and Fig. 3 is a diagram showing an example of recorded results of the rate of reduction in the use of the invention. To explain the inventive features the block diagram, shown in Fig. 1, will be explained in the following:

This diagram shows input length detecting means including a small touch roll 10, a pulse generator 11 and an input length counter 101 for detecting an input length Le of an material 6 being rolled in the mill 8, an input thickness gauge 31 for detecting an actually measured input thickness Gea of the material 6 an input thickness deviation output circuit 33 for feeding a difference ΔGi between the actually measured input thickness Gia fed from the input thickness gauge 31 and input thickness reference value Gis, an input thickness deviation shift register 60 for storing the input thickness deviation Δ Gi fed from the input thickness deviation output circuit 33, successively shifting same in accordance with the measured distances in response to output signal fed from the aforesaid input length counter 101 and feeding data immediately before the positions of the work rolls, a desired reduction output circuit 50 for calculating a desired rate of reduction R from the input thickness reference value Gis and an output thickness reference value Gos and feeding same, output length detecting means including a small touch roll 20, a pulse generator 21 and an output length counter 111 for detecting an output length Lo of the material 6, a calculating circuit 150 for initiating calculation each time a predetermined length is detected by means of the input length counter 101, calculating an estimated input thickness Gic through an equation:

$$Gic\ (ARC) = \frac{Lo}{Li} Gos + \Delta Gi\ (1-r) \qquad (1)$$

or

$$Gic = \frac{Lo}{Li} Gos + \Delta Gi\ (1-r) + c \qquad (2)$$

From the input length Li fed from the input length counter 101, the output length Lo fed from the output length counter 111, the input thickness deviation ΔGi immediately before the positions of work rolls fed from the input thickness deviation shift register 60, the output thickness reference value Gos and the desired rate of reduction are fed from the desired reduction output circuit 50 and feeding an error signal Δx (ARC) between the estimated input thickness Gic (ARC) and the actually measured input thickness Gia fed from the input thickness gauge 31, a correction value calculating circuit 80 for obtaining a calculated output thickness deviation ΔGi (1-r) from the input thickness deviation Gi fed from the input thickness deviation output circuit 33 and the desired rate of reduction R fed from the desired reduction output circuit 50, calculating a feedback correction value C for correcting an error from the calculated output thickness deviation ΔGe (1-r) and the actually measured output thickness deviation ΔGo through an equation

$$C = \frac{\sum_{j=1}^{n} \Delta Go - \sum_{j=1}^{n} \Delta Gi(1-r)}{n} \qquad (3)$$

and feeding same to the calculating circuit 150 a screwdown apparatus 90 including a hydraulic cylinder 91, an electro hydraulic servo-valve 92 and a screwdown servo mechanism 93 for controlling the positions of the work rolls in accordance with the error signal Δx (ARC) fed from the calculating circuit 150 and a recorder 160 and an indicator 161 for recording and indicating a rate of reduction $\frac{Lo-Li}{Lo}$ calculated from the input length Li and the output length Lo in the calculating circuit 150. The inventive method is now as follows:

Firstly, the input length Li is measured such that the number of rotations of the touch roll 10 provided on the center line of the deflector roll 41 disposed forwardly of the mill 8 is converted into pulses by means of the pulse generator 11 and counted by means of the input length counter 101. The digital or analog input length Li thus obtained is fed to the calculating circuit 150.

Subsequently, the actually measured input thickness Gia is measured by means of the input thickness gauge 31 interposed between the deflector roll 41 and the positions of work rolls, compared with the input thickness reference value Gis in the thickness deviation output circuits 33, and the input thickness deviation ΔGi thus obtained is fed to the input thickness deviation shift register 60. The input thickness deviations ΔGi thus supplied are successively shifted in response to outputs from the input length counter 101, whereby the input thickness deviation ΔGi immediately before the positions of work rolls is fed from the shift register 60 to the calculating circuit 150.

The desired rate of reduction r is calculated from the input and output thickness reference signals Gis and Gos, which have been set by the operator, in the desired reduction calculating circuit 50, and then, fed to the calculating circuit 150 as a constant.

The output length is detected by means of the pulse generator 21 of the touch roll 20 being in contact with the deflector roll 42 disposed at the output side of the mill 8, passed through the output length counter 111, and fed to the calculating circuit 150 as the digital or analog output length signal Lo. In the calculating circuit 150, an estimated input thickness Gic is calculated through the equation (1) from the abovedescribed various data, i.e., the input length Li, the output length Lo, the input thickness deviation Gi, the output thickness reference value Gos, and the desired rate of reduction r at every sampling of the input pulse generator 11, an error signal Δx (ARC) between the estimated input thickness Gic and the aforesaid actually measured input thickness Gia fed to the screwdown servo-mechanism 93 of the screwdown apparatus 90. The electro-hydraulic servo-valve 92 controls the reduction action of the hydraulic cylinder 91 in a manner to diminish the aforesaid error signal Δx (ARC) to zero at all times.

In addition, the feedback mechanism is for correcting errors in the rate of reduction due to the difference in diameter between the touch rolls at the input and output sides and the influence of the width spread of the material being rolled is performed by use of the output thickness deviation. More specifically a calculated output thickness deviation is obtained from the input thickness deviation $\Delta Gi\ (1-r)$, the calculated output thickness does obtain this compared with an actually measured output deviation ΔGo and the difference therebetween thus obtained is used as the correction value against the static control disturbance. A correction value C in the equation(3)is obtained everytime after a plurality of n samplings have been conducted and correction is carried out by the form of the equation (2).

The rate of reduction is usually represented by $\frac{(Gi-Go)}{Gi}$.

However, since the position of the thickness gauge is spaces apart from the position of rolling reduction, it is necessary to allow the material 6 to reach the thickness gauge disposed at the output side before the true rate of reduction can be obtained. Consequently to use the strip thickness as the representation of the rate of reduction the complicated mechnism is like tracking system is necessary and the response become low. Therefore, in this invention the rate of reduction is easily obtained by calculating (Lo-Li)/Lo from the actually measured length through the equation $Gic = \frac{Lo}{Li} Go$. The recorder 160 and the indicator 161 respectively record or indicate the rate of reduction Lo = Li/Lo which has been calculated in the aforesaid calculating circuit 150.

Figs. 2 and 3 are recording charts showing the deviation of strip thickness and the rate of reduction in the case of applying the present invention. Fig. 2 shows an example where a test coil being trapezodial shape and having a strip thickness of approximately $\pm$ 10 micrometre is rolled at a certain rate of reduction, in which is best shown the condition that the change in output thickness indicated by D follows the change in input thickness indicated by E. Additionally, according to the record of the rate of reduction, it is found that the material is rolled within $\pm$ 1% with respect to the desired value 9%.

It should be apparent to those skilled in the art, that the inventive method can be carried out with numerals and various other arrangements by those skilled in the art without departing from the spirit and the scope of the invention.

CLAIMS:

1. A method of automatically controlling the rate of reduction in a rolling mill for rolling a material being rolled at a predetermined rate of reduction, the rate of reduction is controlled in such a manner, that an output thickness of the material being rolled is calculated from an actually measured input thickness of the material and a desired rate of reduction based on the principle of the constant mass-flow rate of the material being rolled, an input thickness is estimated from the output thickness first calculated, an input length and an output length, and a difference between the estimated input thickness and an actually measured input thickness can be diminished to zero.

2. A method according to claim 1, wherein said estimated input thickness is feedback corrected by a correction value obtained by adding and averaging a difference between a calculated output thickness deviation and an actually measured thickness deviation of the material being rolled over a predetermined length of material.

FIG. 1

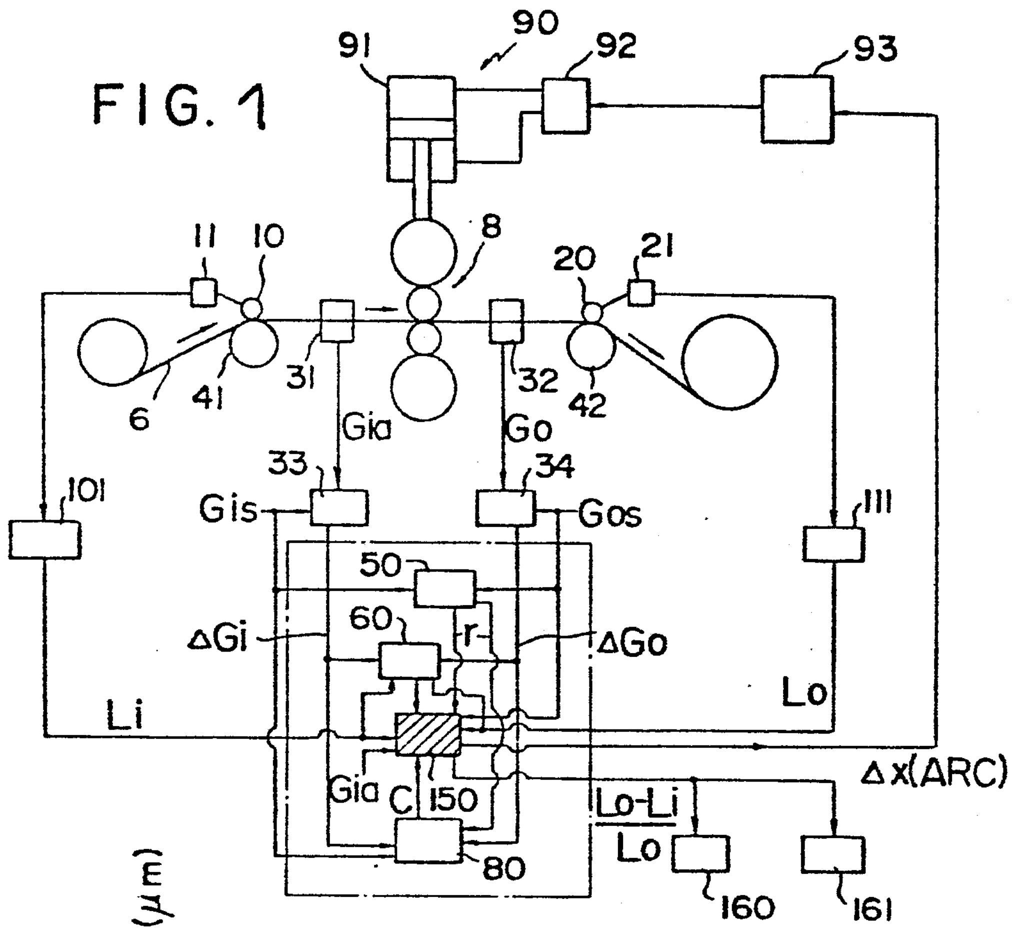

FIG. 2

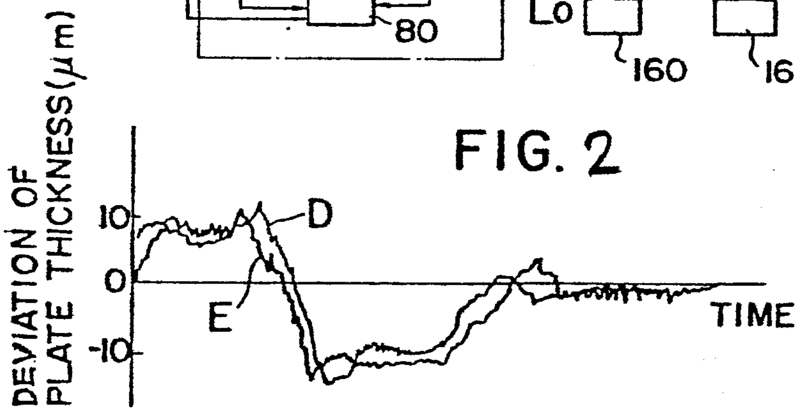

FIG. 3