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[72] Inventors Katumi Hirakawa
Japan;
Hidehiro Kitanosono, Japan; Hiroshi
Nakanishi, Hitachi-Shi, Japan
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[73] Assignee Hitachi Ltd.
Tokyo, Japan
a corporation of Japan
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[54] METHOD OF AND APPARATUS FOR CONTROLLING ROUGHING-DOWN ROLLS OUTLET TEMPERATURE IN HOT ROLLING MILLS

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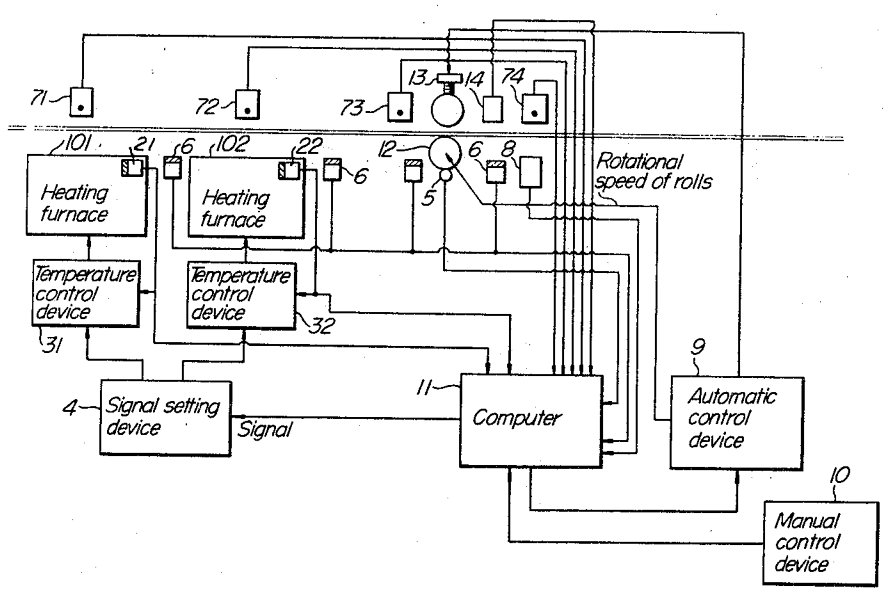
Primary Examiner—William E. Wayner
Attorney—Craig, Antonelli, Stewart & Hill

ABSTRACT: The present invention contemplates to control the temperature of a heating furnace in a hot rolling operation so as to maintain the roughing-down rolls outlet temperature at a desired value in accordance with the roughing-down rolls inlet thickness and outlet thickness, weight of a steel material being rolled, frequency of passage of the steel material through the roughing-down rolls or number of roll stands used, roughing-down rolls outlet width and rotational speed of the rolls.



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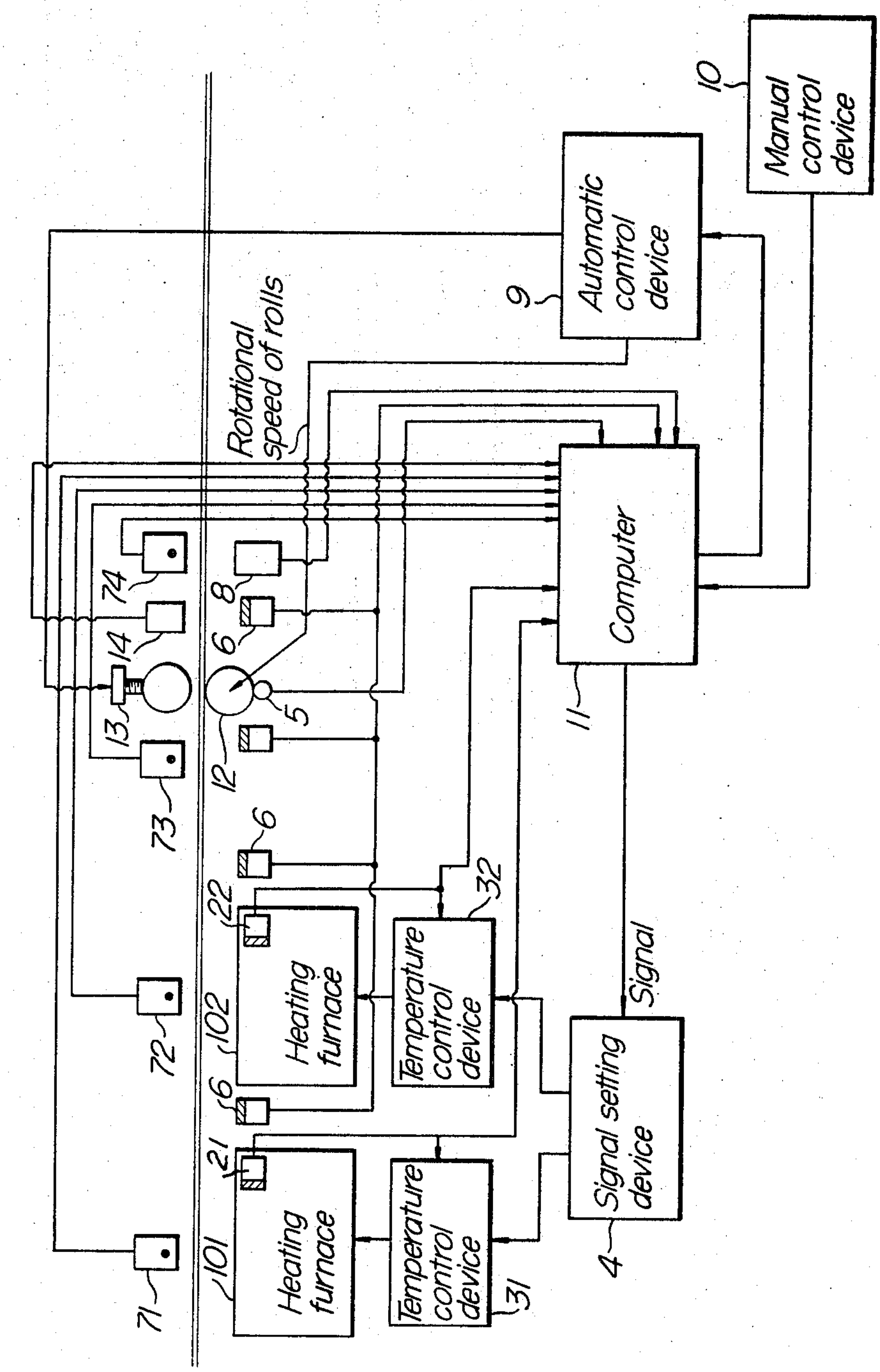

INVENTORS
KATUMI HIRAKAWA
HIDEHIKO KITANOSONO
HIROSHI NAKANISHI

BY Paul M. Craig, Jr.

ATTORNEY

METHOD OF AND APPARATUS FOR CONTROLLING ROUGHING-DOWN ROLLS OUTLET TEMPERATURE IN HOT ROLLING MILLS

The present invention has for its object to control the temperature of a heating furnace in a hot rolling mill so as to maintain the roughing-down rolls outlet temperature at a desired value to thereby ease the control for the succeeding finish rolling operation and minimize a temperature disturbance and ultimately to improve the quality of the finished product.

The terms "roughing-down rolls outlet temperature, thickness or width" and "roughing-down rolls inlet temperature or thickness" as used herein respectively mean the temperature, thickness or width of a steel material being rolled on the steel material discharging side of roughing-down rolls and the temperature or thickness of the steel material on the steel material receiving side of roughing-down rolls.

In hot rolling, the heating operation is generally followed by roughing-down rolling and finish rolling. The temperature of a steel material during the finish rolling is closely related to the mechanical properties, such as tensile strength and elongation, of the finished product. This is because the mechanical properties of rolled steel are related to the crystalline structure is of the steel resulting from the rolling operation and this crystalline structure is variable depending upon the temperature at which said steel is rolled down. Crystalline structure of metals is normally changed drastically at the boundary of a certain temperature which is referred to as the transformation point. The mechanical properties of a steel plate which has been rolled at a temperature above the transformation point are totally different from those of a steel plate which has been rolled at a temperature below the transformation point.

Heretofore, the roughing-down rolls outlet temperature has been controlled merely by maintaining the heating furnace outlet temperature constant and the result has not been satisfactory. The reason for this is that, since the length of a sheet steel being rolled is occasionally as long as 40 to 80 meters from the leading end to the trailing end thereof, a temperature difference of as large as 100° C. may be produced between the leading and trailing end portions and, as a result, the crystalline structure and accordingly the mechanical properties are varied between said end portions.

Moreover, according to the conventional method of controlling the roughing-down rolls outlet temperature by maintaining the heating furnace outlet temperature constant, the finishing rolls outlet temperature of a sheet steel being rolled becomes nonuniform over the entire length of said sheet steel as a result of having been processed through the roughing-down rolls and finishing rolls, even if the rolling operation is performed at a temperature above the transformation point of the sheet steel, and consequently the resistance of the sheet steel against deformation is varied at portions resulting in uneven thickness of the rolled product. In the present rolling industry, it is required for a variation in thickness of rolled products to be controlled below 50 μ for a finishing rolls outlet thickness of 1 millimeter. In view of the fact that a temperature variation of 10° C. precipitates 3 percent variation in resistance to deformation, it is at least necessary to control the temperature variation to below 20° C.

It is the object of the present invention to control the temperature of a heating furnace such that the roughing-down rolls outlet temperature is brought to a desired level, thereby to ease the control for the succeeding finish rolling operation, to minimize a temperature disturbance and to obtain a rolled steel having uniform mechanical properties.

The present inventors have discovered that the roughing-down rolls outlet temperature of a steel material being rolled is influenced by the heating furnace outlet temperature TF, roughing-down rolls inlet thickness HO, roughing-down rolls outlet thickness HN, weight W of the steel material, frequency N of passage of the steel material through the roughing-down rolls (in the case of a reversing rolling mill) or number N of roll stands used (in the case of a tandem rolling mill), roughing-down rolls outlet width B and rotational speed V of the rolls. Based on this discovery, they have arrived at the conclusion that the roughing-down rolls outlet temperature of a steel material could be maintained at a desired level by controlling the heating furnace temperature based on the roughing-down rolls inlet thickness HO, roughing-down rolls outlet thickness HN, weight W of the steel material, frequency N of passage of the steel material through the roughing-down rolls or number N of roll stands used, roughing-down rolls outlet width B and rotational speed V of the rolls. The present invention has been achieved based on the above-mentioned concept.

In order that the present invention may be more clearly understood and readily carried into effect, reference may now be had to the accompanying drawing in which the invention is illustrated by way of example.

Referring to the drawing, a steel material is heated by heating furnaces **101** and **102**. The heating furnaces are respectively provided with temperature detectors **21** and **22**, each including a radiation pyrometer or a photoelectric tube pyrometer, for detecting the temperatures interior of the respective heating furnaces. The temperatures of the heating furnaces are controlled by temperature control devices **31** and **32** respectively which are of a conventional type, for example a PID controller. Reference numeral **4** designates a signal setting device which receives a temperature control signal from a computer **11** and applies said control signal to the respective heating furnace temperature control devices. Reference numeral **5** designates a rotational speed detector for the rolls; while temperature detectors six are provided for detecting the roughing-down rolls outlet temperature; detectors **71, 72, 73** and **74** are provided for detecting the position of the steel material being rolled; a detector **8** is provided for detecting the outlet thickness; an automatic control device **9** is provided for setting therein the rotational speed of the rolls, weight and thickness of the steel material and number of passage of the steel material through the roughing-down rolls or number of roll stands used; a manual control device **10** is provided for setting therein the size of a given steel material and the size (width and thickness) of the finished product; the computer **11** is provided for producing the heating furnace control signal upon receiving the inputs from said group of detectors and control devices; a control device **12** is used for controlling the rotational speed of the rolls; a control device **13** is provided for setting therein the nip of the rolls; and a detector **14** is provided for detecting the outlet width.

Now, it is customary that a steel material discharged from one of a plurality of heating furnaces is reduced by roughing-down rolls and then sent into finishing rolls. In order to bring the roughing-down rolls outlet temperature to a desired level by feeding a temperature control signal to the heating furnaces, the present invention employs two steps of control. The first step is an estimated control in which the roughing-down rolls outlet temperature of the steel material is estimated and the heating furnace temperature is set for that estimated outlet temperature. This step of control is made based on the heating furnace outlet temperature TF, roughing-down rolls inlet thickness HO and outlet thickness HN, weight W of steel material, frequency N of passage of the steel material through the roughing-down rolls or number N of roll stands used, outlet width B and rotational speed V of the rolls.

In general, temperature drop ΔT at the roughing-down rolls is expressed by the function of the following factors, namely:

$$\Delta T = F(HO, HN, TF, N, W, B, V) \qquad (1)$$

For example, the temperature drop 66 T can most simply be expressed by the following equation:

$$\Delta T = a + c\frac{(HO-HN)}{HO} + d(TF-e) + fN + g\frac{W}{HNBV} + hV \qquad (2)$$

wherein *l*, *b*, *c*, *d*, *e*, *f*, *g* and *h* are constants.

Based on this equation, the temperature drop ΔT is calculated by the computer **11** and a signal representing the sum of the calculated value and a value of desired outlet temperature TFO is set in the signal setting device **4**. The heating furnace control device, therefore, operates so as to bring the temperature of the heating furnace to said set value.

The equation (2) which has been obtained by regression analysis of a number of data has the following physical significances.

i. With regard to the second term $c\dfrac{HO-HN}{HO}$ representing the reduction factor, the energy to be given to a steel material by the rolls becomes greater and the temperature drop ΔT becomes smaller as the reduction factors becomes greater. ($c<0$)

ii. With regard to the third term $d(TF-3)$, the temperature drop ΔT becomes greater as the heating furnace outlet temperature TF becomes higher, that is to say, that the higher the temperature of a steel material is, the more the heat is removed therefrom. ($d>0$)

iii. With regard to the fourth term fN, the temperature drop ΔT becomes greater as the frequency N of passage of a steel material through roughing-down rolls or number N of roll stands increases because cooling time is obviously prolonged. ($f>0$)

iv. With regard to the fifth term $g\dfrac{W}{HNBV}$ which is practically expressed in terms of $\dfrac{\text{ton}}{\text{m.}^3\text{ hr.}}$, the temperature drop ΔT becomes greater as the specific gravity of a steel material is greater and the rolling time is extended. ($g>0$)

v. With regard to the sixth term hV, the temperature drop ΔT becomes smaller as the speed increases. ($h<0$)

The second step of control employed in the present invention is a corrective control. For this control, a correcting value of the heating furnace control signal is calculated by the computer **11** using either equation (1) or (2) set forth previously, in accordance with a difference between the actually measured roughing-down rolls outlet temperature **TF1** and a desired temperature **TF0**, represented by:

$$\Delta T = TF1 - TF0 \qquad (3)$$

The heating temperature control device therefore operates according to the correcting value so as to correct the heating furnace temperature. All measurements required for such a control are taken with a proper timing under the control of the steel position detectors **71** through **74**. Namely, when the steel material is still located in the heating furnace, the temperature drop ΔT at the roughing-down rolls is calculated by the computer **11** based on the value set in the manual control device **10** and the heating furnace temperature is controlled by the calculated temperature drop. Now, when the steel material is discharged from the heating furnace, the discharge of the steel material from the heating furnace is detected by the steel position detectors. The temperature of the steel material is then measured and the heating furnace temperature is controlled based on this actual measurement. Thereafter, as the steel material proceeds to the discharging side of the roughing-down rolls, the temperature, thickness and width of the steel material and the rotational speed of the rolls are measured and corrective calculation is conducted at each time of measurement. The results of the calculations are used for the control of the heating furnace temperature. The steel position detectors detect the position of the steel material being rolled and simultaneously select a measurement to be taken which is required for the corrective calculation.

As described hereinabove, since the roughing-down rolls outlet temperature is brought to and maintained at a desired level by controlling the heating furnace temperature in two steps, i.e. be setting an estimated roughing-down rolls outlet temperature of the steel material which is obtained based on such various factors as heating furnace outlet temperature TF, roughing-down rolls inlet thickness HO, roughing-down rolls outlet thickness HN of the steel material, weight W of the steel material, frequency N of passage of the steel material through said rolls or number N of roll stands used, roughing-down rolls outlet width B and rotational speed V of said rolls, and by correcting the heating furnace outlet temperature of the steel material based on the actually measured heating furnace outlet temperature, it is possible according to the present invention to eliminate the temperature difference described previously and to obtain uniform mechanical properties and width over the entire length of the rolled steel.

We claim:

1. A method of controlling rolls outlet temperatures in a hot rolling mill for steel material or the like, comprising:
setting at desired values in a control device the rotational speed of the rolls, the weight and thickness of the steel material and the frequency of passage of the steel material through the rolls or roll stands;
setting at desired values in a second control device the thickness and width of the finished steel material;
initially determining the temperature change of the steel material across the mill based upon a predetermined relationship among the thickness of the steel material at the rolls inlet and rolls outlet, the weight of the steel material, the frequency of passage of the steel material through the rolls or roll stands, the width of the steel material at the rolls outlet and the rotational speed of the rolls;
controlling the operating temperature of a heating furnace at a preliminary operating temperature determined in accordance with the predetermined relationship by adding the temperature change to the desired rolls outlet temperature of the steel material;
measuring the actual rolls outlet temperature of the steel material, measuring the actual rolls outlet thickness of the steel material, and measuring the actual rotational speed of the rolls; and
correcting the preliminarily determined operating temperature of the heating furnace based upon said predetermined relationship in accordance with the actually measured values.

2. A method according to claim **1**, wherein the predetermined relationship for initially determining the temperature change has a general form of

$$\Delta T = a + c\frac{HO-HN}{HO} + d(TF-e) + fN + g\frac{W}{HNBV} + hV$$

wherein $a, c, d, 3, f, g$ and h are constants.

3. A method according to claim **1**, further including controlling the temperature of the heating furnace by a combination of the preliminary operating temperature of the heating furnace and an actual temperature of the heating furnace measured by a thermometer.