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(54) **STEEL MATERIAL COOLING CONTROL METHOD**

VERFAHREN ZUR REGELUNG DER KÜHLUNG VON STAHLMATERIAL

METHODE POUR CONTROLER LE REFRODISSEMENT DE MATERIAU EN ACIER

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Description

TECHNICAL FIELD

5 The present invention relates to a method of cooling a steel, and more specifically to a method for the controlled cooling of a hot rolled steel to a predetermined target temperature.

BACKGROUND ART

10 A hot rolling system forms in general a steel coil by winding a steel sheet being a hot drawn steel after rolling the sheet, with a coiler. To wind up such a steel sheet, the steel sheet should be cooled to a temperature suitable for the winding. In the hot rolling system, the steel sheet is cooled by a cooling system R illustrated in Fig. 5, for example.

As illustrated in the figure, the hot rolling system is constructed such that a finishing rolling machine 1 rolls the steel sheet S, which sheet is then forcedly sent on a run-out table (not shown) in the direction of an arrow A in the figure and wound up by a coiler 6. There is disposed a cooling system R along the run-out table which is to cool the steel sheet S to a temperature suitable for the winding. The cooling system R includes on the side of an inlet thereof an inlet thermometer 2 for measuring the temperature of the steel sheet S to be cooled, and on the side of an outlet thereof an outlet thermometer 5 for measuring the temperature of the steel sheet S after cooled.

20 The cooling system R is separated into two and disposed across vertically the run-out table. Each the separated portion includes a water cooling section 3 for cooling the steel sheet S by pouring water thereon and an air cooling section 4 for cooling the same with air. The air cooling section 4 has the same structure as the water cooling section 3 when the latter stops the pouring of water on the steel sheet S. The water cooling section 3 and the air cooling section 4 disposed on the upper and lower sides of the cooling system R are divided into N cooling banks as designated at numerals 1 through N in the figure, respectively. Each bank is controllable in its cooling capability to cool the steel sheet S.

25 To control the cooling of the steel sheet S by the cooling system R, the cooling system R is divided into a plurality of cooling zones each including the cooling banks of one or more along the run-out table, the cooling capability of each cooling zone being controlled by controlling the amount of supply of a cooling medium (cooling water) from each bank to the steel sheet S in conformity with the travelling of the steel sheet S.

30 It is essential upon controlling the cooling capability of the cooling system R as described above to estimate the amount of the cooling for the steel sheet S, i.e., the amount of a change in the temperature of the same, in each cooling zone. For this, there have hitherto been proposed varieties of techniques to estimate the temperature of the steel sheet S under cooling and execute the cooling control with high accuracy. A technique is known among those techniques described above, as disclosed in Japanese Laid-Open Publication No. 61-199580, wherein learning on heat transfer coefficients and heat emission rates through and from the upper and lower surfaces of the steel sheet S in running is determined by means of a Karman filter.

35 However, steel materials produce some heat in general in their transformation from γ to α iron, for example from austenite to martensite. So, by the just-mentioned technique wherein in cooling capability of a cooling system is learned to estimate the temperature of the steel sheet for controlling the cooling, a problem causes that it is prevented from controlling the temperature of the steel sheet in due consideration of the heat production caused by the transformation of the steel, resulting in the reduced accuracy of the cooling control.

40 On the contrary, to consider the heat production caused by the transformation of a steel material, technique for controlling the cooling in consideration of transformation start timing and transformation time is disclosed in Reference on "Temperature Control in Winding of Hot Drawn High-Carbon Steel" presented at the Sectional Meeting on the 41th Hot Strip held at 1987, Japanese Patent Laid-Open Publication Nos. 57-7312, 58-199613 and 58-125312, etc.

45 In this technique a temperature development of the transformation of a steel material is ignored and the amount of heat production in the transformation remains unchanged without depending on the lapse of time from the initiation of the transformation, and that the total amount of the heat production in the transformation varies in proportion to the lapse of time from the initiation of the transformation. In other words, it is considered in this technique that the amount Q_T of the heat production in the transformation changes stepwise from the transformation initiation as shown in Fig. 6 (A).

50 Furthermore, JP-61-266524 as well as JP-61-110723 disclose techniques of controlling the transformation rate pattern to obtain a predetermined transformation rate in order to achieve a homogenized target material quality. In particular, the two above indicated prior art references teach to control the transformation rate of the steel in order to obtain the target transformation rate. In particular, the last mentioned prior art references teach making use of a target transformation rate which is to be kept constant.

55 However, it should actually be considered that the rate V of the transformation of a steel material indicative of the temporal development of the transformation of the same under cooling changes by a curve as illustrated in Fig. 6 (B), and the amount Q_T of the heat production changes in proportion to the gradient $(\partial W / \partial T)$ of the rate W with respect

to time T. For example, when the rate W of the transformation changes as illustrated to the same figure (B), the gradient ($\partial W / \partial T$) of the rate W changes as illustrated in the same figure (C). Hereby, the actual amount Q_T of the heat production in the transformation changes as illustrated in the same figure (D).

In contrast thereto, the conventional technique just-mentioned above to control the cooling ignores the temporal development of the transformation of a steel but supposing the amount Q_T of the heat production in the transformation being as illustrated in the same figure (A), without taking the actual amount Q_T of the heat production in the transformation which changes as illustrated in the same figure (D), for example, at the initiation and completion of the transformation. So, estimation accuracy depends on accuracy of pre-measured data, and a measuring error directly causes error in cooling control. Then, it has a drawback of the accuracy of temperature estimation being lowered followed by the cooling control with insufficient accuracy.

DISCLOSURE OF THE INVENTION

In view of the drawbacks of the conventional techniques, it is an object of the present invention to provide a control method of cooling a steel capable of accurate cooling control without causing erroneous estimation of steel temperature by determining the amount of cooling on the basis of steel temperature estimated taking the temporal development of the steel transformation upon cooling into consideration.

The above object is achieved by the subject matter of claim 1 which defines a control method of cooling a steel in a cooling system wherein the target temperature is kept constant, whereas the transformation rate is variable.

Preferred embodiments and further improvements of the method are defined in the dependent subclaims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram partly including a cross sectional view, illustrating the whole arrangement of a cooling apparatus associated with a first embodiment of the present invention;

Fig. 2 is a diagram illustrating an example of a cooling bank output pattern executed in a cooling system associated with the first embodiment;

Fig. 3 is a flow chart illustrating an example of a procedure of determining the cooling bank output pattern;

Fig. 4 is a block diagram partly including a cross sectional view, illustrating the whole arrangement of a second embodiment of the present invention;

Fig. 5 is a cross sectional view illustrating an example of a conventional cooling apparatus; and

Fig. 6 is diagrams illustrating an example of a relationship among the conventionally considered amount of heat production caused by transformation, the conventionally considered rate of the transformation, the actual amount of heat production caused by transformation, and the actual change in the rate of the transformation.

BEST MODE FOR CARRYING OUT THE INVENTION

In what follows, the present invention will be described in detail with reference to the accompanying drawings.

The invention provides a control apparatus wherein the control method of the present invention is executed to cool a hot drawn steel with use of a cooling system R in a cooling apparatus located on a hot drawing line as illustrated in Fig. 1. The cooling system R is of the same construction as that shown in Fig. 5, wherein the steel sheet S rolled through the finishing rolling machine 1 is successively wound up by the coiler 6 through the cooling system R. The finishing rolling machine 1 disposed on the inlet side of the cooling system R includes an inlet speed detector 10 for detecting the carrying speed of the steel sheet S carried after rolled by the finishing rolling machine 1. In addition, the coiler 6 disposed on the outlet side of the cooling system R includes an outlet speed detector 12 for detecting the wind-up speed of the steel sheet S. There are further provided inlet and outlet thermometers 2, 5 on the inlet and outlet sides of the cooling system R.

Here, the like symbols shall be applied to the like configurations and operations as those in the conventional cooling system illustrated in Fig. 5, and detailed description is omitted.

The cooling system R includes a predetermined number of cooling zones, each zone having at least one cooling bank. The pouring amount of coolant (for example, water) from the cooling bank is controlled to control the cooling of the steel sheet S passing through each cooling zone.

Here, the inlet thermometer 2, inlet speed detector 10 and outlet speed detector 12 shown in Fig. 1 transmit re-

spective detection signals to a cooling bank output pattern determining unit 14. The cooling bank output pattern determining unit 14 determines by computation a pattern to control the cooling capability of each cooling bank according to a cooling time t (hereinafter, referred to as a cooling bank pattern) for obtaining the desired temperature decrease of the steel sheet S in response to the cooling time t based upon the inputted inlet side temperature, the carrying speed of the steel sheet S , the wind-up speed, a preset target temperature of the steel sheet S and sheet thickness, etc.. The cooling bank pattern determined as described above is inputted into a cooling bank switching input/output unit 16. The cooling bank switching input/output unit 16 controls the cooling capability of each cooling bank in response to the inputted cooling bank pattern.

Cooling results of pouring water by each bank of the cooling system R controlled by the bank switching input/output unit 16 are fed into a learning control unit 18. The learning control unit 18 receives detection signals from the inlet speed detector 10, the output speed detector 12, the inlet thermometer 2, and the outlet thermometer 5, and learns the cooling capability of the cooling system R on the basis of the inputted aforesaid cooling results and the detection signals.

The change in the temperature of the steel sheet S after the lapse of predetermined time is estimated on the basis of the cooling time of the steel sheet S and of the cooling capability of the cooling system R . At the same time, the amount of heat production of the steel sheet S , for example, due to the transformation of the same is calculated in the response to the temporal development of the transformation caused by the cooling of the steel sheet S . Then, the error of the estimated change in the temperature of the steel sheet S is corrected by the calculated amount of heat production of the steel sheet S due to the transformation of the same. Then the cooling bank pattern of the cooling system R is determined for cooling control so as to provide the corrected amount of the change in the temperature of the steel sheet S .

It will first be described how the temporal development of the transformation of the steel sheet S is obtained.

The rate W of the transformation of the steel sheet S under cooling can be calculated from the following equation (1) as a function of the cooling time t .

$$W = 1 - \exp [A \cdot (t/B)^C] \quad (1)$$

Here, A , B , and C are parameters determined by the component, temperature, thickness, and cooling pattern of each steel sheet S . More specifically, A is a parameter for calculating the rate of the transformation, B and C are coefficients for learning. The accuracy of estimating the rate W of the transformation can be increased by correcting the coefficients for learning according to the learning results based on signals from a plurality of sensors for detecting the transformation rate, disposed in the cooling system.

The transformation rate sensor comprises by a combination of an exiting coil and magnetic detecting element, for example, and the transformation rate is detected by measuring phase transformation through a change in magnetic permeability.

It is possible to know the temporal development of the transformation of the steel sheet S with respect to time by the equation (1). In addition, the means to know the temporal development of the transformation of the steel sheet S is not limited to the one which utilizes the relationship of the equation (1). Instead, the transformation rate sensor to directly detect the rate of the transformation can be used.

On the assumption that in the cooling system R including the cooling zones of the predetermined number, the cooling time from the inlet side to the i th cooling zone is t_i , the amount of the change in the rate of the transformation $\Delta W_i (= W_i - W_{i-1})$ in the i th cooling zone can be calculated on the basis of the cooling time $t_i (= t_i - t_{i-1})$ in the i th cooling zone and the equation (1).

The amount of heat production Q_{Ti} of the steel sheet S due to the transformation in the i th cooling zone when the amount of the change in the rate of the transformation ΔW_i , is given by the following equation (2).

$$Q_{Ti} = H * \Delta W_i \quad (2)$$

Here, H is latent heat of the steel sheet S upon the transformation (a physical quantity which can be determined from the component of the steel sheet S , the kind of the same, and the temperature of the same).

Therefore, the amount of heat production Q_T upon the transformation in each cooling zone when the steel sheet S is cooled from the inlet temperature FDT to the target temperature CT is calculated by using the equation (2). Then the temperature change of the steel sheet S estimated from the cooling time of the steel sheet S and the capability of the cooling system R is corrected by the amount of heat production Q_{Ti} upon the transformation so calculated. In consequence, the accurate temperature change of the steel sheet S as the sheet passes through each cooling zone

can be estimated.

To realize the temperature change so estimated in each cooling zone, the number of the water pouring banks in each cooling zone is determined with use of the following temperature model equation (3) which shows the temperature change ΔT_{iw} in water cooling in the i th cooling zone and the following temperature model equation (4) which shows the temperature change ΔT_{ia} in air cooling in the i th cooling zone. By using the above relations, cooling can be controlled so as to give desired temperature change to the steel sheet S considering the amount of heat production Q_T upon the transformation, namely the temporal development of the transformation.

$$\begin{aligned} \Delta T_{iw} = & \left\{ 1 / C_P \cdot \rho \cdot h \cdot \int_{t_{i-1}}^{t_i} \alpha_{ui} \right. \\ & \times (T_i - T_w) dt \} \\ & + \left\{ 1 / C_P \cdot \rho \cdot h \cdot \int_{t_{i-1}}^{t_i} \alpha_{di} \right. \\ & \times (T_i - T_w) dt \} \\ & + Q_{Ti} / (C_P \cdot \rho) \quad \dots (3) \end{aligned}$$

$$\begin{aligned} \Delta T_{ia} = & 1 / C_P \cdot \rho \cdot h \\ & \times \int_{t_{i-1}}^{t_i} \left\{ C \cdot [(T_{air} + 273) ^4 \right. \\ & / 100 ^4 + (T_i + 273) ^4 \\ & / 100 ^4] \\ & - \alpha_{ROLL} \cdot (T_i - T_w) dt \} \\ & + Q_{Ti} / (C_P \cdot \rho) \quad \dots (4) \end{aligned}$$

Here, C_p is the specific heat, ρ the specific gravity, α_{ui} the coefficient of cooling capacity of each upper cooling bank, α_{di} the coefficient of cooling capacity of each lower cooling bank, T_i the temperature of the steel sheet S at the inlet of the i th cooling zone, T_w the temperature of the cooling water, C_j the emission constant, α_{ROLL} the heat transfer coefficient (for the associated roll), and T_{air} is air temperature.

Here, Fig. 2 illustrates the cooling bank pattern. The cooling bank pattern is a target of the temperature change to be realized for the steel sheet S in each cooling bank when the steel sheet S is cooled by the cooling system R from the inlet temperature FDT to the target temperature CT. In the figure, a symbol A denotes a temperature change curve by air cooling (hereinafter, referred to as an air cooling curve A), and a symbol B denotes a temperature change curve by water cooling (hereinafter, referred to as a water cooling curve B). In the first embodiment, the cooling system R shares the cooling between the cooling zones to a predetermined one located in the vicinity of the inlet for the water cooling and those located in the vicinity of the outlet for the air cooling. For this, the water cooling curve B passes through the inlet temperature FDT, while the air cooling curve A passing through the target temperature CT.

The water cooling curve B is obtained by calculating the temperature change ΔT_{iw} using the equation (3) when water pouring valves are opened in succession from the first cooling bank to actuate the respective cooling zones to the i th cooling zone. In this situation, to take the amount of the heat production Q_{Ti} due to the transformation into consideration, the calculated temperature change ΔT_{iw} is corrected by the amount of the heat production Q_{Ti} due to the transformation calculated by the equation (2). In the same manner, the air cooling curve A is obtainable by correcting the temperature change ΔT_{ia} calculated using the equation (4) by the aforementioned amount of the heat production Q_{Ti} due to the transformation. Here, a hatched portion designated at a symbol Q_T in the figure corresponds to the temperature rise of the steel sheet S which might be caused by the amount of the heat production Q_T in the transformation, for correction the cooling curves A, B.

It should be noted here that in a cooling zone at an intersection between the water and air cooling curves B and A (hereinafter, the zone is assumed to be a mth one), a cooling curve designated at C in the figure (hereinafter, referred to as a water cooling curve C) is required for changing smoothly the temperature of the steel sheet S from T_m to T_{m+1} . For this, the cooling capacity of the cooling banks in the aforementioned mth cooling zone is adjusted. The adjustment of the cooling capacity is done by changing the number of the water pouring cooling banks in the zone.

In succession, a procedure of determining the cooling bank pattern illustrated in Fig. 2, which is to be done in the cooling bank output pattern determining unit 14, will be described with reference to a flow chart shown in Fig. 3.

After starting the apparatus, the various parameters are first inputted into the cooling bank output pattern determining unit 14 in Step 105. The parameters include the target temperature CT , the cooling pattern of each bank, the inlet temperature FDT , the inlet speed, the outlet speed, and the thickness of the steel sheet S, etc. Then, the amount of heat production Q_{Ti} of the steel sheet S under cooling is calculated by the equation (2) in Step 110.

In Step 120, the temperature change ΔTi by the air cooling by each cooling bank is calculated by the equation (4) for determining the cooling curve A which passes through the target temperature CT .

In Step 130, the temperature change ΔTiw by the water cooling by each cooling bank is calculated for determining the water cooling curve B. The calculation is done in succession starting from the 1st cooling zone until the water cooling curve B resulting from the present calculation becomes less than the air cooling curve A calculated in Step 120. The details are as follows.

That is, in Step 131 cooling zones, for which the temperature changes ΔTiw have been calculated, are set in succession. In Step 132 the total of the temperature changes ΔTiw up to the finally set cooling bank is calculated. And in Step 133, it is judged whether or not a value of the total temperature change subtracted from the inlet side temperature FDT , i.e., the water cooling curve B is smaller than the air cooling curve A. If the result is negative, i.e., the value of the water cooling curve B is larger than the value of the air cooling curve A, then the operation advances to Step 134 to increment by 1 the number of the associated cooling zone ($i = i + 1$), and returns to Step 132 for calculating the total of the temperature changes ΔTiw of the cooling zones up to the incremented number by 1, i.e., of the $(i + 1)$ th cooling zone to calculate the value of the water cooling curve B in the cooling zone for the judgement in Step 133.

On the contrary, if the result in Step 133 is positive, i.e., if the value of the cooling curve B is judged to be smaller than the value of the cooling curve A, then the operation advances to Step 140. Here, a cooling zone, which first gives the positive result, is assumed to be a mth one. Thus, values giving the water cooling curve B are evaluated in succession up to the just-mentioned mth cooling zone.

In the above Step 140, in order to achieve the cooling control in the mth cooling zone such that the steel sheet S is changed in its temperature following the water cooling curve C, the number of the water pouring banks, is determined by calculation. The number of the water pouring banks is determined such that the temperature T_m of the steel sheet S on the entrance side of the present cooling zone becomes a temperature T_{m+1} of the air cooling curve A on the exit side of the same. The completion of the calculation in this Step 140 gives the cooling bank output pattern.

The cooling bank output pattern such as illustrated in Fig. 2 as determined by the cooling bank output pattern determining unit 14 as described above is inputted into a cooling bank switching input/output unit 16. The cooling bank switching input/output unit 16 controls the pouring of water in each cooling bank according to the inputted cooling bank output pattern while inputting results of the pouring in each cooling bank into the learning control unit 18.

The learning control section 18 learns the inputted pouring results, the inlet speed of the steel sheet S, the output speed of the same, and the inlet and outlet temperature, etc., and supplies to the bank output pattern determining unit 14 data for determination of the optimum cooling bank output pattern for the successive cooling control based upon the learned values.

As in the second embodiment shown in Fig. 4, a plurality of transformation rate sensor 20 are disposed in the cooling system R. Learning coefficient for calculating the actual rate of the transformation is calculated in a transformation rate calculating unit 22 based on output signal from the respective transformation rate sensors 20 and inputted into the learning control unit 18 as is the first embodiment. Then, the learning coefficient used in the equation (1) is corrected.

Namely, when the actual rates $\bar{W}_i$, $\bar{W}_j$ of the transformation under cooling are obtained from the transformation rate sensors 20 disposed in the cooling system R, the learning coefficients B, C in the equation (1) are expressed as follows:

$$C' = \ln (\ln \bar{W}_i / \ln \bar{W}_j) / \ln (t_i / t_j) \quad (5)$$

$$B' = t_i \{ (1/A) \ln \bar{W}_i \}^{-1/C'} \quad (6)$$

where,

W_i is a transformation rate at sensor i

t_i is a cooling time until sensor j

B', C' are learning coefficients calculated from actual values.

Then, the learning coefficients B and C are calculated by the following equations (7) and (8).

$$B = (1 - G) * B + G * B' \quad (7)$$

$$C = (1 - G) * C + G * C' \quad (8)$$

where G is a coefficient for weighting.

By using the learning coefficients B , C and the equation (1), the temporal development of transformation can be corrected by learning.

The optimum cooling control of the steel sheet S is thus assured by taking the temporal development of the transformation into consideration using the heat production of the steel sheet S caused by the transformation of the same.

Here, although in the above embodiments such a cooling bank output pattern as illustrated in Fig. 2, i.e., a cooling pattern for water cooling from the inlet side of the cooling apparatus was described. Another cooling bank output pattern is possible according to the present invention without limitation to the cooling where the illustrated cooling bank output pattern is pursued. That is, such modifications are achievable in response to cooling condition. For example, a cooling bank output pattern, where the first half of the cooling system R performs the air cooling while the second half of the same performing the water cooling, can be obtained by constructing the cooling bank output pattern such that the water cooling curve B reaches the target temperature CT and the air cooling curve A reaches the inlet temperature FDT . In addition, other arbitrary cooling patterns can be obtained in the cooling control by each cooling zone by continuously controlling the poured water from each bank and the degree of the air cooling by each bank without limitation to the above-described procedure where any cooling pattern was determined by the pouring the water from each cooling bank and by the interruption of the pouring.

Furthermore, although in the above embodiments the cooling apparatus for a steel sheet transferred on the hot rolling line was described as illustrated examples, the present invention may be applied for lines and steels without limitation thereto. For example, the present invention can be applied to steels such as thick steel, line steel, rod steel when they are cooled after hot processing.

CAPABILITY OF EXPLOITATION IN INDUSTRY

The present invention is most suitable in particular for use, in a cooling zone of a cooling system for cooling a hot drawn steel, in cooling the steel to a temperature of suited to the winding of the steel.

Claims

1. A method of cooling a steel in a cooling system by controlled cooling of the steel to a target temperature, the method comprising the steps of:
determining the temporal development of the steel by determining the rate W of a phase transformation of the steel as a function of cooling time and thereafter calculating the heat produced during said transformation, wherein the rate W of transformation is evaluated by the following formula as a function of the cooling time t :

$$W = 1 - \exp [A \cdot (t/B)^C]$$

where A , B and C are parameters defined by the component, temperature, thickness and geometrical cooling pattern of each steel used;

estimating the temperature change of the steel for a time period based on cooling time of the steel and cooling capability of the cooling system;

correcting error in the estimated temperature change by using the calculated heat produced during transformation;

calculating a cooling bank pattern from parameters including the target temperature, the determined heat produced during transformation, and the corrected temperature change; and

determining a target temperature pattern on the basis of the cooling bank pattern and controlling the cooling system to cool the steel to a target temperature based upon the calculated cooling bank pattern.

2. A method of cooling a steel according to claim 1, **characterized in that** the rate W of transformation is detected by using a transformation rate sensor (20).
3. A method of cooling a steel sheet according to claim 1, wherein the cooling capability of the cooling system is established by learning the results of the cooling, the speed of carrying the steel and the detected temperature.
4. A method of cooling a steel according to claim 1 **characterized in that** said cooling control is conducted by changing the amount of cooling water of each cooling bank and/or number of working banks according to the amount of cooling.
5. A method of cooling a steel according to claim 4, wherein said cooling control is conducted by combining water cooling and air cooling according to a combination of separate temperature curves which are based on an inlet temperature and outlet temperature, respectively, a number of water poured banks are changed at a cooling zone where both cooling curves intersect with each other, and cooling is conducted according to a cooling curve with combines both cooling curves.
6. A method of cooling a steel sheet according to claim 1, wherein parameters in a control model are tuned based upon results of control so as to increase the accuracy of the control model.
7. A method of cooling a steel according to claim 2, wherein the rate of transformation is corrected by the following equations in response to an output from transformation rate sensors,

$$C' = \ln (\ln \bar{W}_i / \ln \bar{W}_j) / \ln (t_i/t_j),$$

$$B' = t_i \{ (1/A) \ln \bar{W}_i \}^{-1/C'}$$

$$B = (1 - G) * B + G * B',$$

and

$$C = (1-G) * C + G * C',$$

where $\bar{W}_i$, $\bar{W}_j$ are measured rates of the transformation by sensors i and j;

t_i , t_j are the cooling time from an inlet side to an ith or jth cooling zone, and

G is the coefficient for weighting.

Patentansprüche

1. Verfahren zum Kühlen eines Stahles in einem Kühlsystem durch auf eine Zieltemperatur geregelte Kühlung des Stahles, wobei das Verfahren die folgenden Schritte umfaßt:

Bestimmen der zeitlichen Entwicklung des Stahles durch Bestimmen des Verhältnisses W einer Phasenumwandlung des Stahles als einer Funktion der Kühlzeit und danach Berechnen der während dieser Umwandlung freigesetzten Wärme, wobei das Verhältnis W der Umwandlung durch die folgende Gleichung als eine Funktion der Kühlzeit t berechnet wird:

$$W = 1 - \exp [A \cdot (t/B)^C],$$

worin A , B und C durch die Komponente, die Temperatur, die Dicke und die geometrische Kühl-Charakteristik jedes verwendeten Stahles definierte Parameter sind;

Schätzen der Temperaturänderung des Stahles während einer Zeitspanne, welche auf der Kühlzeit des Stahles und der Kühlleistung des Kühlsystems basiert;

Korrigieren des Fehlers in der geschätzten Temperaturänderung durch Verwendung der während der Umwandlung freigesetzten berechneten Wärme;

Berechnung einer Kühlbett-Charakteristik aus Parametern, einschließlich der Zieltemperatur, der während der Umwandlung freigesetzten bestimmten Wärme, und der korrigierten Temperaturänderung; und

Bestimmen einer Zieltemperatur-Charakteristik auf Grundlage der Kühlbett-Charakteristik und Regeln des Kühlsystems, um den Stahl auf eine Zieltemperatur, welche auf der berechneten Kühlbett-Charakteristik basiert, zu kühlen.

2. Verfahren zum Kühlen eines Stahles nach Anspruch 1, **dadurch gekennzeichnet**, daß das Verhältnis W der Umwandlung durch Verwendung eines Umwandlungsverhältnis-Sensors (20) detektiert wird.

3. Verfahren zum Kühlen eines Stahlbleches nach Anspruch 1, wobei die Kühlleistung des Kühlsystems durch Lernen der Ergebnisse des Kühlens, der Transportgeschwindigkeit des Stahles und der detektierten Temperatur hergestellt wird.

4. Verfahren zum Kühlen eines Stahles nach Anspruch 1, **dadurch gekennzeichnet**, daß die Kühlregelung durch Ändern der Menge des Kühlwassers jedes Kühlbettes und/oder der Anzahl der Arbeitsbetten entsprechend der Kühlmenge durchgeführt wird.

5. Verfahren zum Kühlen eines Stahles nach Anspruch 4, wobei die Kühlregelung durch Kombinieren von Wasserkühlung und Luftkühlung entsprechend einer Kombination aus getrennten Temperaturkurven durchgeführt wird, welche jeweils auf einer Einlaßtemperatur und einer Auslaßtemperatur basieren, eine Anzahl von Wassergießbetten in einem Kühlbereich geändert wird, wo beide Kühlkurven sich schneiden, und Kühlen entsprechend einer Kühlkurve, welche beide Kühlkurven kombiniert, durchgeführt wird.

6. Verfahren zum Kühlen eines Stahlbleches nach Anspruch 1, wobei die Parameter in einem Regelmodell auf der Grundlage der Ergebnisse der Regelung eingestellt werden, um die Genauigkeit des Regelmodells zu erhöhen.

7. Verfahren zum Kühlen eines Stahles nach Anspruch 2, wobei das Verhältnis der Umwandlung durch die folgenden Gleichungen in Reaktion auf eine Ausgabe aus den Umwandlungsverhältnis-Sensoren korrigiert wird,

$$C' = \ln (\ln \bar{W}_i / \ln \bar{W}_j) / \ln (t_i / t_j)$$

$$B' = t_i \{ (1/A) \ln \bar{W}_i \}^{-1/C'}$$

$$B = (1-G) \cdot B + G \cdot B'$$

und

$$C = (1 - G) * C + G * C'$$

worin $\overline{W}_i$, $\overline{W}_j$ die gemessenen Verhältnisse der Umwandlung durch die Sensoren i und j sind;

t_i , t_j die Kühlzeiten von einer Einlaßseite zu einem i-ten oder j-ten Kühlbereich sind und

G der Gewichtungskoeffizient ist.

Revendications

1. Procédé de refroidissement d'un acier dans un système de refroidissement grâce à la commande du refroidissement de l'acier jusqu'à une température cible, le procédé comprenant les étapes consistant à :

déterminer la mise au point dans le temps de l'acier en déterminant la cadence W d'une transformation de phase de l'acier en fonction du temps de refroidissement et ensuite en calculant la quantité de chaleur produite au cours de ladite transformation, dans lequel la cadence W de transformation est évaluée grâce à la formule suivante en fonction du temps de refroidissement t :

$$W = 1 - \exp [A \cdot (t/B)^C]$$

dans laquelle A, B et C sont des paramètres définis par le composant, la température, l'épaisseur et le modèle géométrique de refroidissement de chaque acier utilisé;

évaluer les changements de température de l'acier pendant une période de temps basée sur le temps de refroidissement et la capacité de refroidissement du système de refroidissement ;

corriger les erreurs dans les changements de température estimés en utilisant la quantité de chaleur produite, calculée, au cours de la transformation ;

calculer un modèle de refroidisseur à partir des paramètres comprenant la température cible, la quantité de chaleur produite, déterminée, au cours de la transformation, et les changements de température corrigés ; et déterminer un modèle de température cible sur la base du modèle de refroidisseur et commander le système de refroidissement afin de refroidir l'acier jusqu'à une température cible basée sur le modèle calculé de refroidisseur.

2. Procédé de refroidissement d'un acier selon la revendication 1, caractérisé en ce que la cadence W de transformation est détectée en utilisant un détecteur de cadence de transformation (20).

3. Procédé de refroidissement d'une feuille d'acier selon la revendication 1, dans lequel la capacité de refroidissement du système de refroidissement est établie en consultant les résultats du refroidissement, la vitesse de transport de l'acier et la température détectée.

4. Procédé de refroidissement d'un acier selon la revendication 1, caractérisé en ce que ladite commande du refroidissement est conduite en modifiant la quantité d'eau de refroidissement dans chaque refroidisseur et/ou le nombre de refroidisseurs en fonctionnement selon la quantité du refroidissement.

5. Procédé de refroidissement d'un acier selon la revendication 4, dans lequel ladite commande du refroidissement est conduite en combinant le refroidissement à l'eau et le refroidissement à l'air selon une combinaison de courbes de températures séparées qui sont basées sur une température à l'entrée et une température à la sortie, respectivement, un certain nombre de refroidisseurs arrosés à l'eau est changé au niveau d'une zone de refroidissement dans laquelle les deux courbes de refroidissement se coupent, et le refroidissement est conduit selon une courbe de refroidissement qui combine les deux courbes de refroidissement.

6. Procédé de refroidissement d'une feuille d'acier selon la revendication 1, dans lequel les paramètres du modèle de commande sont accordés, en se fondant sur les résultats de la commande de façon à augmenter la précision du modèle de commande.

7. Procédé de refroidissement d'un acier selon la revendication 2, dans lequel la cadence de transformation est

EP 0 453 566 B1

corrigée grâce aux équations suivantes en réponse à une sortie en provenance des détecteurs de cadence de transformation,

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$$C' = \ln (\ln \bar{W}_i / \ln \bar{W}_j) / \ln (t_i / t_j)$$

$$B' = t_i \{ (1/A) \ln \bar{W}_i \}^{-1/C'}$$

10

$$B = (1 - G) * B + G * B',$$

et

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$$C = (1 - G) * C + G * C',$$

dans lesquelles $\bar{W}_i$, $\bar{W}_j$ sont des cadences de la transformation mesurées par les détecteurs i et j ; t_i et t_j sont les temps de refroidissement entre un côté entrée et une ième ou jème zone de refroidissement et G est le coefficient de pondération.

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FIG. 1

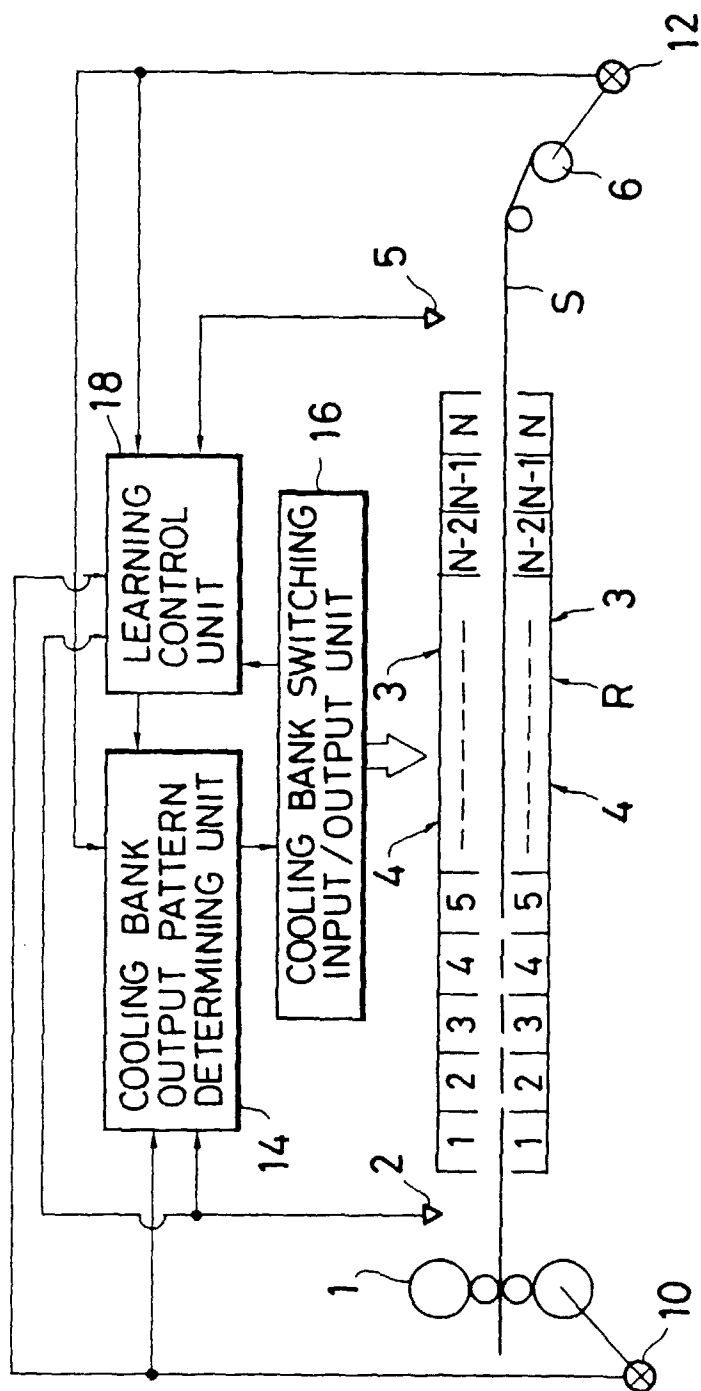


FIG.2

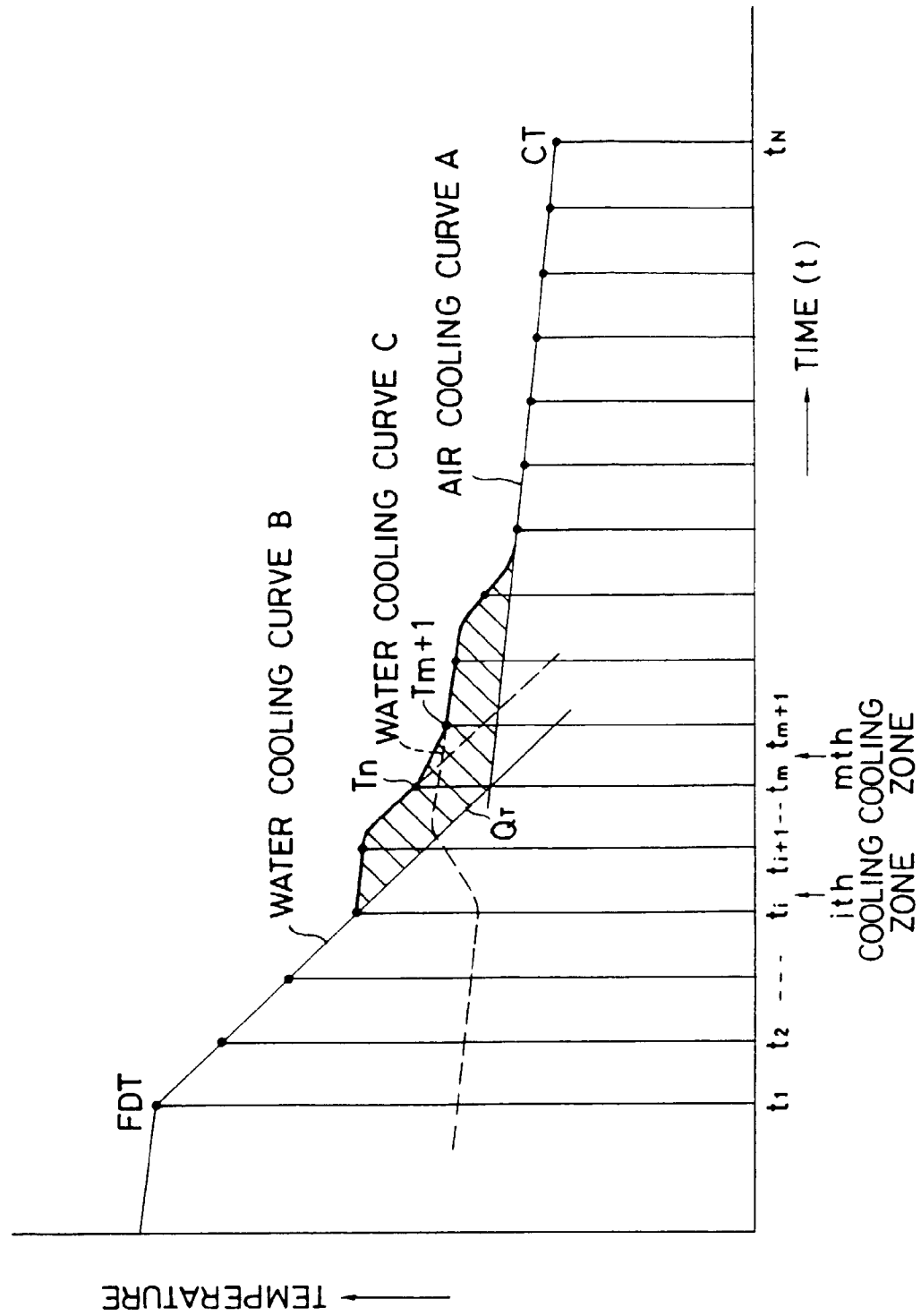


FIG. 3

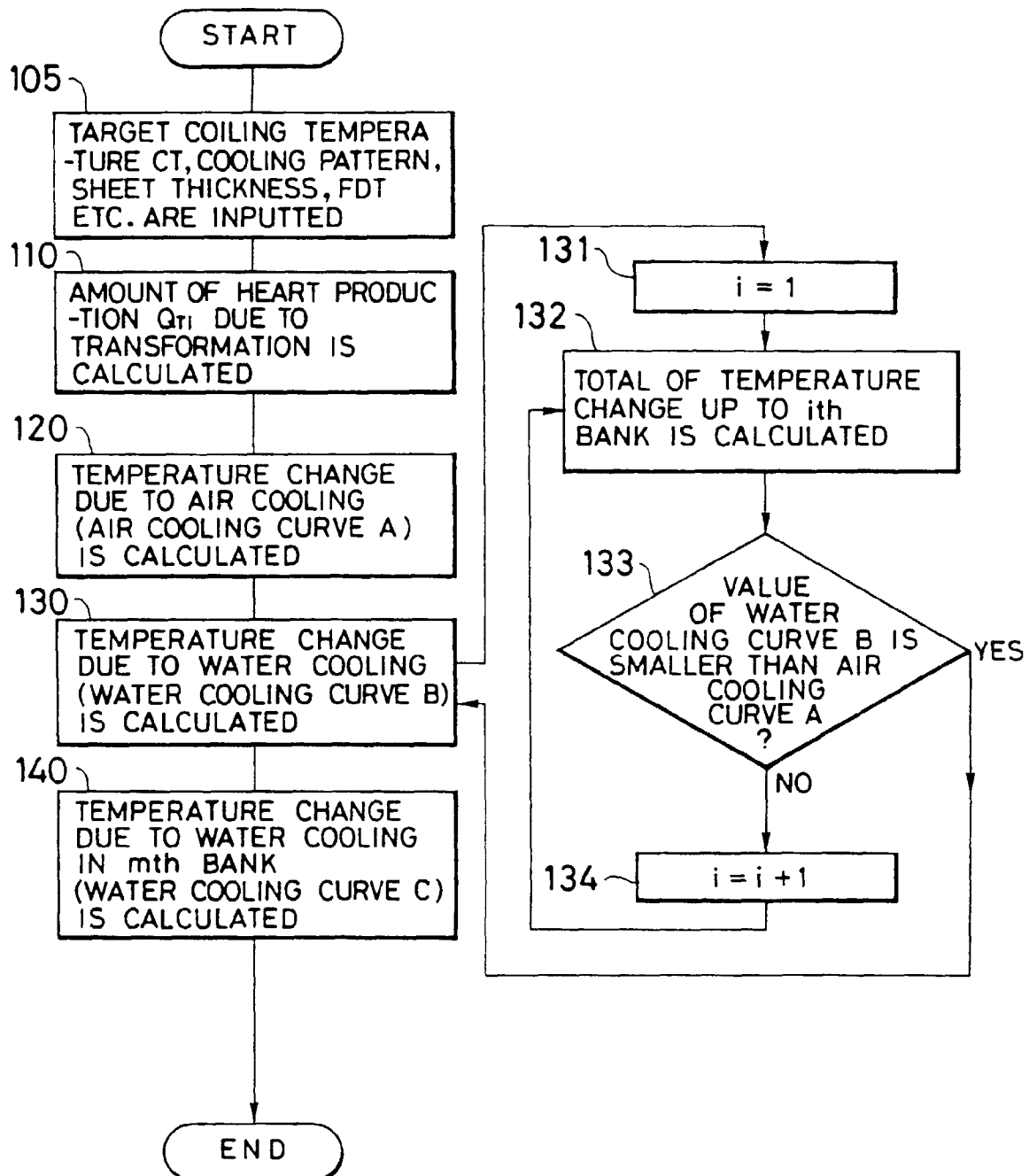


FIG. 4

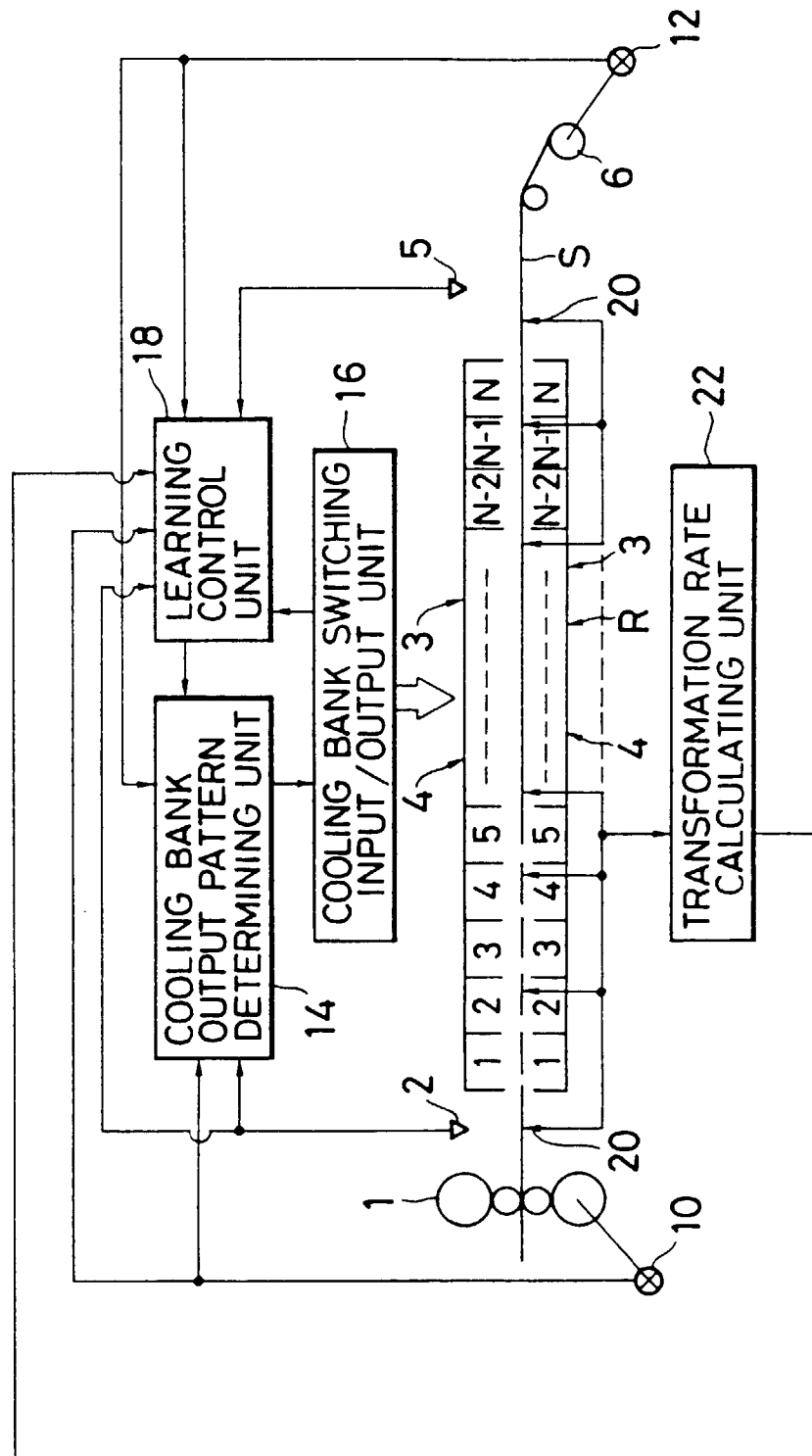


FIG.5

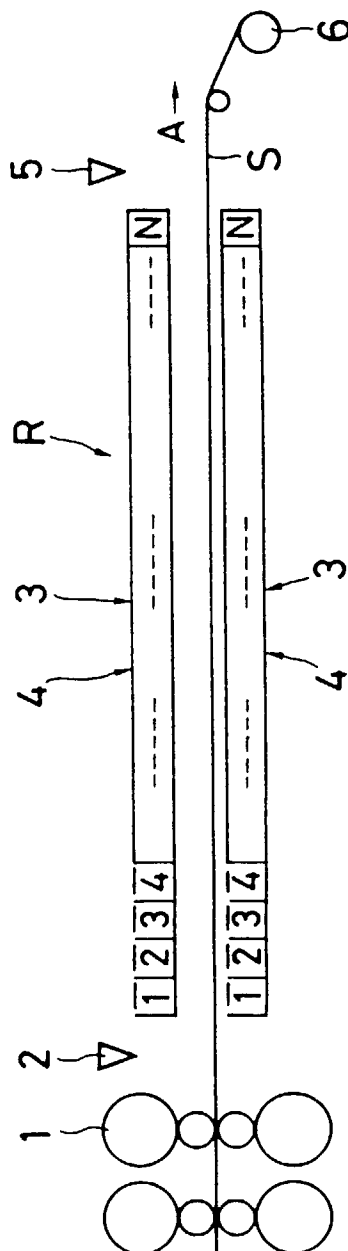


FIG. 6 (A)

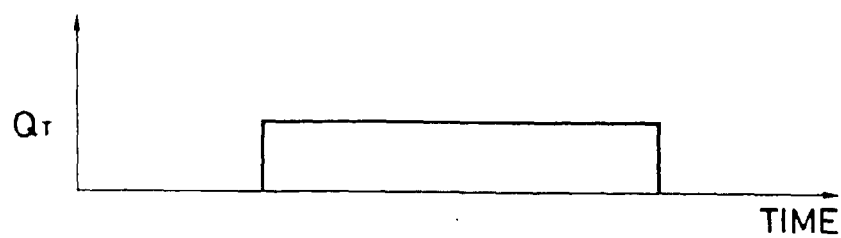


FIG. 6 (B)

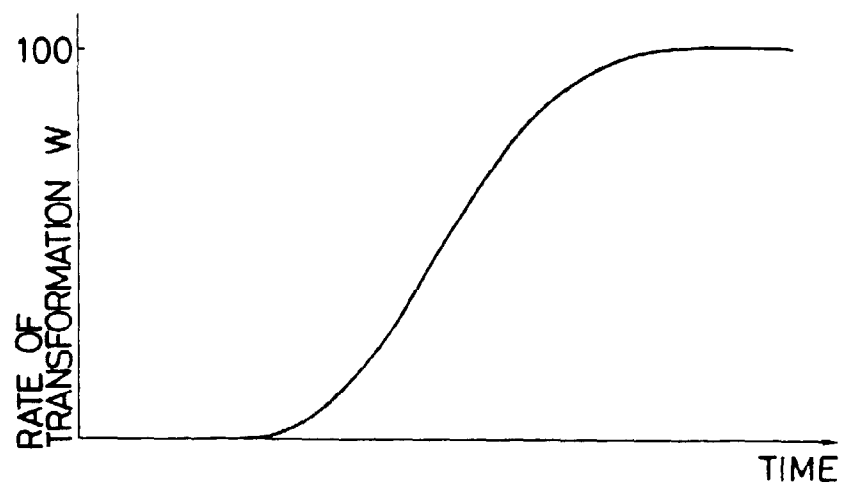


FIG. 6 (C)

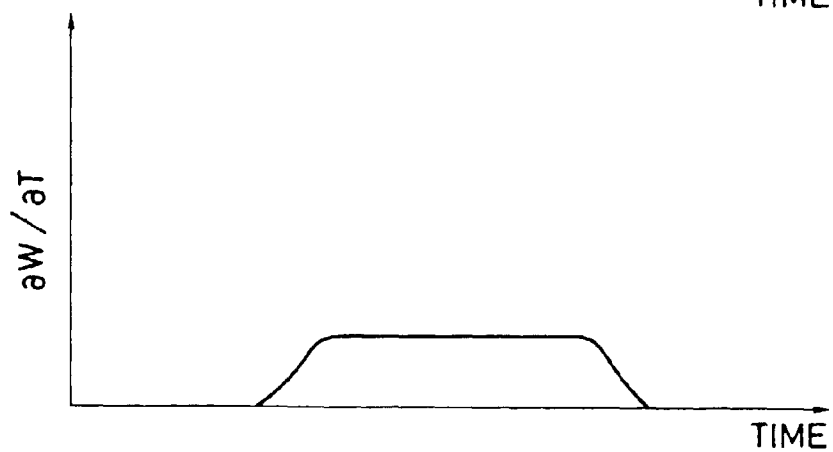


FIG. 6 (D)

