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(71) Applicant: KABUSHIKI KAISHA TOSHIBA  
Kawasaki-shi, Kanagawa-ken 210 (JP)

(72) Inventors:  
• Sekiguchi, Kunio  
Kawagoe-shi, Saitama-ken (JP)  
• Anbe, Yoshiharu  
Kodaira-shi, Tokyo-to (JP)

(74) Representative: Zangs, Rainer E., Dipl.-Ing. et al  
Hoffmann, Eitle & Partner  
Arabellastrasse 4/VIII  
81925 München (DE)

(54) Hot rolling method and apparatus

(57) Disclosed is a hot rolling method and a hot strip mill which can manufacture a thin strip easily, while attaining a low energy consumption and a high productivity. In a hot rolling method such that at least a continuous casting installation (7), a tunnel furnace (14), a rolling mill (10), a strip shear (11) and a down coiler (6) are arranged in sequence; a single slab manufactured by the continuous casting installation is kept warmed or heated by the tunnel furnace; the slab taken out of the tunnel furnace is rolled to a target strip thickness by the rolling mill; the rolled strip is coiled by the down coiler; and the rolled strip is cut off plural times so that the coiled rolled strip becomes a predetermined length, the target strip thickness on the outgoing side of the rolling mill is changed under rolling conditions, in order to man-

ufacture a plurality of coils of different strip thicknesses from the same rolling plate. Further, when the rolling machine is composed of a roughing mill (12) and a finishing mill (13), the roughing and finishing mills are arranged close to each other; the slab kept warm or heated by the tunnel furnace is rolled to a bar having a target thickness by the roughing mill; the bar is continuously rolled to a target strip thickness by the finishing mill; and the bar thickness is changed in the roughing mill and/or the target strip thickness is changed in the finishing mill, under rolling conditions, in order to manufacture a plurality of coils of different strip thicknesses from the same rolling plate.

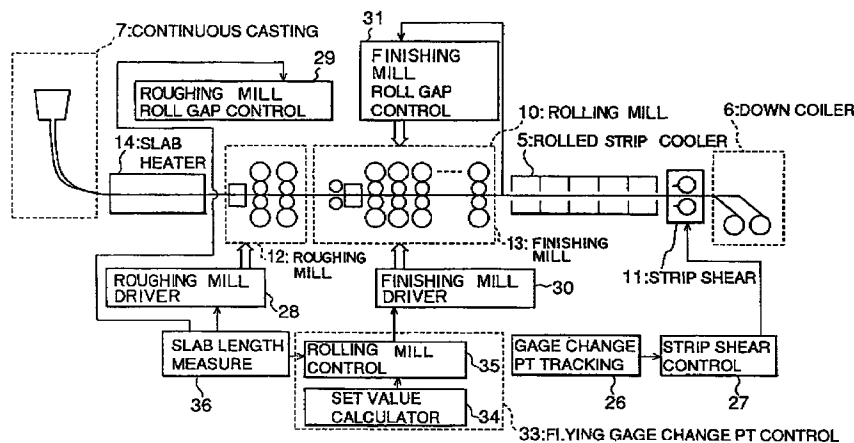


FIG. 4

**Description****BACKGROUND OF THE INVENTION**5 **Field of the Invention**

The present invention relates to a hot rolling method and machine for continuously rolling a heated steel plate or sheet.

10 **Description of the Prior Art**

Fig. 6 is a line construction of a prior art hot strip mill for realizing a typical hot rolling method for rolling a heated steel plate. By this hot strip mill, a rolled plate, that is, a slab having a thickness of 200 to 260 mm, a width of 600 to 1800 mm and a length of 2 to 20 m can be rolled to a coiled strip having a strip thickness of about 1 to 12 mm. A heating  
 15 furnace 1 heats a conveyed slab up to about 1100°C, and then extracts the heated slab onto a slab conveying table. The heated and extracted slab is passed through a descaling installation 2 to remove iron oxide formed on the surface of the slab, and then conveyed to a roughing mill 3. The roughing mill 3 is generally composed of a plurality of vertical rolling mill and horizontal rolling mill to roll the slab both in the thickness and width directions. The thickness of the slab can be reduced down to about 40 mm, and then conveyed to a finishing mill 4. The finishing mill 4 is generally com-  
 20 posed of horizontal rolling mill of 4 to 6 stands, to roll the thickness of the roughly rolled strip down to 1 to 12 mm. The rolled strip taken out of the finishing mill is cooled to a target coiling temperature by a rolled strip cooling installation 5, and then coiled into a coil by a down coiler 6.

In summary, the hot strip mill as shown in Fig. 6, the slab is heated, and then the heated slab is rolled for each slab, and then coiled into a coil.

25 Fig. 7 shows another prior art line construction of the hot strip mill for directly rolling slab manufactured by a continuous casting installation, which is disclosed in Magazine "Iron and Steel Engineer", 36 to 41 page, December 1993.

In this hot strip mill, a slab with a thickness of 50 mm is manufactured by a continuous casting installation 7. The slab is cut off down to such a length as to provide a predetermined weight by a shear 8 installed on the outgoing side of the continuous casting installation 7, and then conveyed to a tunnel furnace 9. The conveyed slab is heated up to  
 30 1080°C to 1150°C by the tunnel furnace 9, and then fed to a rolling mill 10. The rolling mill 10 composed of a plurality of horizontal rolling mill rolls the slab to a predetermined thickness. The rolled strip taken out of the rolling mill is cooled down to a target coiling temperature by a rolled strip cooling installation 5, and then coiled by a down coiler 6 into a coil. In general, this continuous casting installation can manufacture the slab of about 150 tons at once. Therefore, when a coil of about 25 ton is manufactured, the casted slab is cut off into a six slabs, and then rolled. In other words, in the hot  
 35 strip mill as shown in Fig. 7, even when the continuously casted thin slab is directly rolled, the slab must be divided into a small slab, and after that the slab must be rolled for each slab, and then coiled into a coil for each slab.

Here, the hot strip mill as shown in Fig. 6 is provided with such a large production capability as to heat and roll a great amount of slab in sequence. Here, however, since the slab before heated is generally kept at a normal temperature, the slab must be heated up to about 1100°C. Therefore, the energy required to heat the slab by the furnace is  
 40 huge.

On the other hand, in the hot strip mill as shown in Fig. 7, since the temperature of slab continuously casted is as high as about 900°C, the energy required to heat the slab through the tunnel furnace is relatively very small, as compared with the case of the hot strip mill as shown in Fig. 6. However, since the production amount is restricted by the continuous casting installation or the production capacity of the rolling mill, the energy required for the hot rolling  
 45 machine as shown in Fig. 7 is about 1/2 to 1/3 of the energy required for the hot rolling machine as shown in Fig. 6.

Further, in the case of the prior art hot strip mill for rolling the strip for each slab, the so-called plate head threading work is required for each slab. In this strip head threading work, the rolled strip head must be passed through a rolling mill composed of a plurality of stands and then coiled by the down coiler. For instance, in the strip head threading work shown in Fig. 6, a top end of the strip rolled by the finishing mill 4 is passed through the rolled plate cooling installation  
 50 5, and then reaches the down coiler 6.

Therefore, until the top end of the rolled strip reaches the down coiler 6, the rolled strip is conveyed to the down coiler 6 by a conveying force of the finishing mill 4 and a conveying force of a table roller disposed between the finishing mill 4 and the down coiler 6. In other words, until the top end of the rolled strip reaches the down coiler 6, since the rolled strip is only kept restricted on the table rollers by the weight of the rolled strip, there arises such a trouble that the rolled  
 55 strip is floated away from the table rollers by a wind pressure or a cooling water pressure applied to the lower side of the rolled strip by the rolled strip cooling installation 5, with the result that a corrugation phenomenon occurs in the rolled strip and thereby the rolled plate cannot reach the down coiler.

This corrugation phenomenon occurs easily when the strip thickness becomes small, so that there exists so far a problem in that it is impossible to manufacture the rolled strip with a thickness less than 1.0 mm under stable conditions.

SUMMARY OF THE INVENTION

With these problems in mind, therefore, it is the object of the present invention to provide a hot rolling method and the apparatus for realizing the same method, which can easily manufacture a relatively thin strip, while satisfying both a low energy consumption and a high productivity.

To achieve the above-mentioned object, the present invention provides a hot strip mill having at least a continuous casting installation, a rolled plate heating installation, a rolling mill, a strip shear, and a down coiler, all being arranged in sequence, for keeping warm or heating a rolled strip manufactured through the continuous casting installation by the rolled plate heating installation, for rolling the heated rolled plate to a target strip thickness by the rolling mill, for coiling the rolled strip by the down coiler, and for cutting off the coiled rolled strip into a predetermined length by the strip shear, which comprises: a rolled plate length measuring unit for measuring a length beginning from a top end of the rolled plate going out of the rolled plate heating installation, and outputting a timing signal when a strip thickness change point previously determined on the rolled strip reaches the rolling mill; a flying gage change control unit including: a set value calculating section for calculating a roll gap set value and a roll speed set value of the rolling mill; and a rolling mill control section for changing a roll gap set value and a roll speed set value of the rolling mill, under rolling (running) conditions, on the basis of the roll gap set value and the roll speed set value both calculated by said set value calculating section and in response to the timing signal outputted by said rolled strip length measuring unit; a strip thickness change point tracking unit for detecting a strip thickness change point position on an outgoing side of the rolling mill; and a strip shear control unit for cutting off the rolled plate by the strip shear according to the output of said plate thickness change point tracking unit, in order to manufacture coils of different strip thicknesses continuously from the same rolled plate.

Further, the present invention provides a hot strip mill having at least a continuous casting installation, a rolled plate heating installation, a roughing mill, a finishing mill, a strip shear, and a down coiler, all being arranged in sequence and further the roughing and finishing mill being arranged close to each other, for keeping warm or heating a rolled plate manufactured through the continuous casting installation by the rolled plate heating installation, for rolling the heated rolled plate to a bar having a target thickness by the roughing mill and further continuously rolling the rolled bar to a target strip thickness by the finishing mill, for coiling the rolled strip by the down coiler, and for cutting off the coiled rolled strip into a predetermined length by the strip shear, which comprises: a rolled strip length measuring unit for measuring a length beginning from a top end of the rolled strip going out of the rolled strip heating installation, and outputting a timing signal when a plate thickness change point previously determined on the rolled plate reaches the roughing mill; a flying gage change control unit including: a set value calculating section for calculating a roll gap set value and a roll speed set value of the roughing mill and a roll gap set value and a roll speed set value of the finishing mill, respectively; a rolling mill control section for changing a roll gap set value and a roll speed set value of each of the rough and finish rolling mill, under rolling conditions, on the basis of the roll gap set values and the roll speed set values both calculated by said set value calculating section and in response to the timing signal outputted by said rolled plate length measuring unit; a strip thickness change point tracking unit for detecting a strip thickness change point position on an outgoing side of the finishing mill; and a strip shear control unit for cutting off the rolled plate by the strip shear according to the output of said strip thickness change point tracking unit, in order to manufacture coils of different strip thicknesses continuously from the same rolled plate.

Further, in the hot strip mill, it is preferable that the roughing mill comprises a vertical rolling mill for rolling the rolled mill in a width direction thereof, and a horizontal rolling mill for rolling the rolled plate in a thickness direction thereof; said rolled plate length measuring unit measures a length beginning from a top end of the rolled plate going out of the rolled plate heating installation, and further detects a timing at which the previously determined strip thickness change point reaches the vertical rolling mill; and the hot rolling mill further comprises a flying bar width control unit including: a set value calculating section for calculating a roll opening rate set value of the vertical rolling mill in order to change a bar width at the strip thickness change point; and a rolling mill control section for changing a roll opening rate of the vertical rolling mill, under rolling conditions, on the basis of the vertical rolling mill roll opening rate set value calculated by said set value calculating section and in response to the timing outputted by said rolled strip length measuring unit, in order to manufacture a plurality of coils of different strip thicknesses and/or different strip widths continuously from the same rolled plate.

Further, the present invention provides a hot rolling method, comprising the steps of: arranging at least a continuous casting installation, a tunnel furnace, a rolling mill, a strip shear, and a down coiler in sequence; keeping warm or heating a single rolled plate manufactured through the continuous casting installation by the tunnel furnace; rolling the rolled plate taken out of the tunnel furnace to a target strip thickness by the rolling mill; coiling the rolled strip by the down coiler; cutting off the rolled strip plural times so that the coiled rolled strip becomes a predetermined length; changing a target strip thickness on the outgoing side of the rolling mill, under rolling conditions, in order to manufacture a plurality of coils of different strip thicknesses from the same rolling plate.

Further, the present invention provides a hot rolling method, comprising the steps of: arranging at least a continuous casting installation, a tunnel furnace, a roughing mill, a finishing mill, a strip shear, and a down coiler in sequence,

the rough and finish rolling mill being arranged close to each other; keeping warm or heating a single rolled plate manufactured through the continuous casting installation by the tunnel furnace; rolling the rolled plate taken out of the tunnel furnace to a bar having a target thickness by the roughing mill; continuously rolling the bar to a target strip thickness by the finishing mill; coiling the rolled strip by the down coiler; cutting off the rolled strip plural times so that the coiled rolled strip becomes a predetermined length; changing the bar thickness of the roughing mill and/or changing the target strip thickness of the finishing mill, under rolling conditions, in order to manufacture a plurality of coils of different strip thicknesses from the same rolling plate.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a line construction of a first embodiment of the hot strip mill for realizing the hot rolling method according to the present invention;

Fig. 2 is a view showing the relationship between the rolling speed and the rolling time, for assistance in explaining the operation of the first embodiment shown in Fig. 1;

Fig. 3 is a view showing the relationship between the slab length and the flying gage change point, for assistance in explaining the operation of the first embodiment shown in Fig. 1;

Fig. 4 is a line construction of a second embodiment of the hot strip mill for realizing the hot rolling method according to the present invention;

Fig. 5 is a line construction of a third embodiment of the hot strip mill for realizing the hot rolling method according to the present invention;

Fig. 6 is a line construction of a first example of the hot strip mill for adopting a prior art hot rolling method;

Fig. 7 is a line construction of a second example of the hot strip mill for adopting another prior art hot rolling method; and

Fig. 8 is a view showing the relationship between the rolling speed and the rolling time, for assistance in explaining the operation of the hot strip mill for adopting the prior art hot rolling method.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to the detailed description of the embodiments, the function of the present invention will be described hereinbelow together with the principle thereof.

In the prior art hot rolling method as explained with reference to Fig. 7, the productivity of the rolling mill is reduced mainly when a thin coil is required to be rolled. In the ordinary rolling operation for each slab, a series of operation such as rolled strip head threading work, acceleration, steady rolling, deceleration, and rolled strip tail-out work are repeatedly performed. Here, in order to improve the rolling stability, the rolling speed  $V_{TH}$  (i.e., threading speed) of when the rolled strip head is passed or threaded through and the rolling speed  $V_{OUT}$  (i.e., tail-out speed) of when the rolled plate tail is passed out are both determined lower than the rolling speed  $V_{RUN}$  (i.e., running speed) at the steady rolling, as shown in Fig. 8. For instance, in Fig. 8, when a rolled strip having a thickness less than 2 mm is rolled, the head threading speed  $V_{TH}$  is determined as 600 mpm (meter per min); the steady rolling speed  $V_{RUN}$  is determined as 1200 mpm; and the tail-out speed  $V_{OUT}$  is determined as 900 mpm. Further, as understood by Fig. 8, there exists an idle time during which the rolling is disabled between the respective two coils. Although the idle time is necessary for the preparation of the succeeding rolling work, when this idle time can be eliminated, it is possible to improve the productivity markedly. Further, in general, since the work troubles are concentrated during the head threading operation and the tail-out operation, the thinner the strip thickness is, the more often will occur the trouble. Accordingly, in the prior art hot rolling method as shown in Fig. 7, when the time required for the head threading work and the tail-out work can be reduced in the rolling mill, it is possible to increase the productivity and decrease the energy at the same time, while facilitating the rolling work of a thin sheet less than 1 mm.

With these considerations in mind, therefore, in the hot strip mill according to the present invention such that a single slab manufactured by the continuous casting installation is kept warm or heated; the slab is rolled to a target strip thickness and coiled; and the rolled strip is cut off so that the length thereof becomes a predetermined length under rolling (running) conditions, the rolling mill comprises in particular a flying (during-rolling) gage (strip thickness) change control unit for changing the target strip thickness under rolling conditions. In this case, since a plurality of coils of different strip thicknesses can be manufactured from the same single slab, the head threading work and the tail-out work can be reduced markedly, so that the idle time during which no rolling work is performed between two coils can be eliminated. As a result, a thin sheet rolling is enabled easily, while satisfying both a low energy consumption and a high productivity, so that a versatile production can be realized.

Further, to further increase the productivity, it is effective to increase the thickness of the slab. For instance, in the hot rolling method as shown in Fig. 7 for instance, the slab thickness is 50 mm. In this case, however, if this thickness is increased up to 150 mm, the productivity can be simply increased three times. However, when the slab thickness is

increased, two rolling machines (rough and finish rolling mill) are required as shown in Fig. 6, due to the relationship between the rolling mill and the thickness reduction capacity.

To cope with the above-mentioned rolling conditions, in the hot strip mill according to the present invention, the rough and finish rolling mill are arranged close to each other, in order to shorten the line length, to reduce the equipment cost, and to reduce the bar temperature drop. In addition, the slab manufactured by the continuous casting installation is cut off after rolled (without being cut off before rolled) to improve the productivity. Further, when a plurality of coils of different strip thicknesses are required from the same slab for the reasons of a production plan, the target strip thicknesses are changed, under rolling conditions, in at least one of the roughing mill and the finishing mill. In this case, since the coils of different strip thicknesses can be also manufactured from the same slab, a thin sheet rolling is enabled easily, while satisfying both a low energy consumption and a high productivity, so that a versatile production can be realized.

Further, when considering the flexibility of the production schedules, it is preferable to continuously roll a plurality of coils of different strip widths. For this purpose, in the hot rolling apparatus according to the present invention, the toll opening rate of the vertical rolling mill for constituting the roughing mill is changed, under rolling conditions, in such a way that the bar width can be changed, with the result that it is possible to manufacture a plurality of coils of different strip widths from the same slab. Therefore, the rolling work can be made at a low energy consumption and with a high productivity, so that a versatile production can be realized.

Further, in the hot rolling method according to the present invention, a plurality of coils of different strip thicknesses can be manufactured from the same slab, by changing the outgoing side target plate thickness of the rolling mill, under rolling conditions.

Further, in the hot rolling method according to the present invention, a plurality of coils of different strip thicknesses can be manufactured from the same slab, by changing the flying (during-rolling) bar thickness of the roughing mill and/or the target strip thickness of the finishing mill, both under rolling conditions.

A first embodiment of the hot rolling mill for realizing the hot rolling method according to the present invention will be described hereinbelow with reference to Fig. 1. In Fig. 1, a slab manufactured by the continuous casting installation 7 is fed to a slab heating installation 14 such as a tunnel furnace, without being cut off as with the case of the prior art method as explained with reference to Fig. 7. After having been heated to a predetermined incoming side temperature by the slab heating installation 14, the slab is fed to a rolling mill 10.

The fed heated slab is rolled to a target strip thickness by the rolling mill 10, cooled down to a predetermined coiling temperature by a rolled strip cooling installation 5, and then coiled into a coil by a down coiler 6. Here, when the weight or the length of the coil now being coiled reaches a predetermined value, the rolled strip is cut off under rolling by a strip shear 11 installed on the incoming side of the down coiler 6. After having been cut off, the rolled strip existing on the down coiler side is coiled as it is. On the other hand, the rolled strip existing on the rolling mill side is conveyed to another down coiler and then coiled as another coil.

Fig. 2 shows a speed pattern of the first embodiment of the rolling mill (shown in Fig. 1) for rolling n-units of coils by use of a single slab. For the first coil, since the rolled strip head threading work is required, the slab is passed through the rolling mill at a head threading speed  $V_{TH}$ , and then accelerated up to a steady rolling (or running) speed  $V_{RUN}$ . In the embodiment shown in Fig. 1, since the tail-out work is required for only the n-th coil (without need of the tail-out work for the other coils), the other coils are kept rolled at the steady rolling speed  $V_{TH}$ . Here, however, immediately before the boundary between the first and second coils reaches the strip shear, the rolling speed is reduced down to a speed  $V_c$  (e.g., 1000 mpm) at which the rolled strip can be cut off by the strip shear, so that the strip shear can cut off the rolled strip at the boundary between the first and second coils. After that, the rolling speed is accelerated up to the steady rolling speed  $V_{RUN}$  again.

In general, there exists such a need of manufacturing coils of different strip thicknesses by use of the same slab, on the basis of the production plan. In this case, when the target strip thickness is changed under rolling conditions (i.e., during rolling work), it is possible to manufacture a plurality of coils of different strip thicknesses by use of the same slab. Therefore, in the cold rolling mill composed of a plurality of stands, the target strip thickness is often changed under rolling conditions, that is, during cold rolling. In addition, the flying (during-rolling) target gage (strip thickness) changing technique of a hot rolling mill is already described by "Flying gage change control by hot finishing mill", page 181 to 184, Lecture Papers, 36-th Plastic Working Joint Lectures (6 to 8, October, 1985).

However, this prior art flying strip gage change technique is a method in which a strip thickness control for controlling the strip thickness on the outgoing side of the respective stands and a mass flow control for reducing the mass flow change are both combined with each other.

The present invention adopts a flying (during-rolling) gage (strip thickness) changing technique different from the prior art changing technique as follows:

Fig. 3 shows a state of strip thickness changes obtained when five coils of different strip thicknesses are manufactured by use of the same slab. Each of the strip thickness change points is each boundary between two coils, which are denoted by GCP1 to GCP4. The slab lengths  $L_1$  to  $L_4$  between the slab top end and the respective strip thickness change points GCP1 to GCP4 are previously determined according to the production plan.

In the slab length measuring equipment 25 shown in Fig. 1 measures the slab length after the slab top end is engaged with the first stand of the rolling mill 10, for instance, and further outputs the respective timings at which the respective strip thickness change points GCP1 to GCP4 (as shown in Fig. 3) reach the first stand F1. The respective slab lengths can be obtained by integrating the slab speed with respect to time, and the slab speed can be obtained on the basis of the first stand rolling speed and the first stand backward slip.

Here, the case where the strip thickness is changed between i-th and (i+1)-th stands under rolling conditions in the rolling mill constructed by seven stands F1 to F7 will be considered by way of example. Table 1a lists the relationship between the roll gap set values and the stands through which the strip thickness change points CPG1 to CPG7 pass; and Table 1b lists the relationship between the roller speed set values and the stands through which the strip thickness change points CPG1 to CPG7 pass; in which

$S_{j,i}$ : j-th stand roll gap set value of i-th coil

$V_{j,i}$ : j-th stand roll speed set value of i-th coil

In Tables 1a and 1b, before the strip thickness change point reaches the F1 stand, since i-th coil is being rolled, the roll gap set value and the roll speed set value are both the values set for the i-th coil.

Here, however, when the strip thickness change point passes through the F1 stand to the F7 stand in sequence, as listed in Table 1a, the roll gap set value  $S_i$  of the i-th coil is changed to the set value  $S_{i+1}$  for the (i+1)-th coil.

On the other hand, as listed in Table 1b, the roll speed set values of all the stands arranged on the upstream side of the stand at which the strip thickness change point arrives are changed. In other words, when the stand at which the strip thickness change point arrives is denoted by k, the roll speed set values of the stand at which the strip thickness change point arrives is set to  $V_{kk}$ , and the roll speed set values of the stands arranged on the upstream side of the stand k are changed to  $V_{jk}$  (j = 1 to (k-1)), respectively.

$$\bar{V}_{kk} = \frac{V_{k,i}(1 + (f_{k,i}))}{1 + f_{kk}} \quad (1)$$

$$\bar{V}_{jk} = \frac{h_{k,i+1} \cdot \bar{V}_{kk} \cdot (1 + f_{kk})}{h_{j,i+1} \cdot (1 + f_{j,i+1})} \quad (2)$$

where

$V_{k,i}$ : k stand roll speed set value (mpm) of i-th coil

$f_{k,i}$ : k stand forward slip (-) of i-th coil

$f_{kk}$ : k stand forward slip (-) through which thickness change point passes

$h_{k,i+1}$ : k stand outgoing side target thickness (mm) of (i+1)-th coil

$h_{j,i+1}$ : j stand outgoing side target thickness (mm) of (i+1)-th coil

$f_{j,i+1}$ : j stand forward slip (-) of (i+1)-th coil

Here, when the strip thickness change point passes through the k stand, since the roll gap set value is changed to the set value of the (i+1)-th coil, the outgoing side strip thickness is changed to the target strip thickness of the (i+1)-th coil.

In this case, when the tension between k and (k+1) stands maintains the i-th value, the k stand outgoing side plate speed must be maintained at the i-th value. The above formula (1) is derived on the basis of this relationship.

Further, in the 1 to (k-1)-th stands, since the (i+1)-th coil has been already rolled, when the k stand roll speed is changed, the roll speed set value is changed so that the mass flow rule as expressed by the above formula (2) can be satisfied. Further, whenever the strip thickness change point passes through the F7 stand, all the stands are set to the (i+1)-th coil roll speed set values.

Table 1a

|     | F1          | F2          | F3          | F4          | F5          | F6          | F7          |
|-----|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| *F1 | $S_{1,i}$   | $S_{2,i}$   | $S_{3,i}$   | $S_{4,i}$   | $S_{5,i}$   | $S_{6,i}$   | $S_{7,i}$   |
| F1  | $S_{1,i+1}$ | ↓           | ↓           | ↓           | ↓           | ↓           | ↓           |
| F2  | ↓           | $S_{2,i+1}$ | ↓           | ↓           | ↓           | ↓           | ↓           |
| F3  | ↓           | ↓           | $S_{3,i+1}$ | ↓           | ↓           | ↓           | ↓           |
| F4  | ↓           | ↓           | ↓           | $S_{4,i+1}$ | ↓           | ↓           | ↓           |
| F5  | ↓           | ↓           | ↓           | ↓           | $S_{5,i+1}$ | ↓           | ↓           |
| F6  | ↓           | ↓           | ↓           | ↓           | ↓           | $S_{6,i+1}$ | ↓           |
| F7  | ↓           | ↓           | ↓           | ↓           | ↓           | ↓           | $S_{7,i+1}$ |

Table 1b

|     | F1             | F2             | F3             | F4             | F5             | F6             | F7          |
|-----|----------------|----------------|----------------|----------------|----------------|----------------|-------------|
| *F1 | $V_{1,i}$      | $V_{2,i}$      | $V_{3,i}$      | $V_{4,i}$      | $V_{5,i}$      | $V_{6,i}$      | $V_{7,i}$   |
| F1  | $\bar{V}_{11}$ | ↓              | ↓              | ↓              | ↓              | ↓              | ↓           |
| F2  | $\bar{V}_{12}$ | $\bar{V}_{22}$ | ↓              | ↓              | ↓              | ↓              | ↓           |
| F3  | $\bar{V}_{13}$ | $\bar{V}_{23}$ | $\bar{V}_{33}$ | ↓              | ↓              | ↓              | ↓           |
| F4  | $\bar{V}_{14}$ | $\bar{V}_{24}$ | $\bar{V}_{34}$ | $\bar{V}_{44}$ | ↓              | ↓              | ↓           |
| F5  | $\bar{V}_{15}$ | $\bar{V}_{25}$ | $\bar{V}_{35}$ | $\bar{V}_{45}$ | $\bar{V}_{55}$ | ↓              | ↓           |
| F6  | $\bar{V}_{16}$ | $\bar{V}_{26}$ | $\bar{V}_{36}$ | $\bar{V}_{46}$ | $\bar{V}_{56}$ | $\bar{V}_{66}$ | ↓           |
| F7  | $V_{1,i+1}$    | $V_{2,i+1}$    | $V_{3,i+1}$    | $V_{4,i+1}$    | $V_{5,i+1}$    | $V_{6,i+1}$    | $V_{7,i+1}$ |

In both Tables 1a and 1b, F1 to F7 arranged horizontally in the uppermost row denote the numbers of the stands; F1 to F7 arranged vertically in the leftmost column denote the stands through which the strip thickness change point pass; and the set values  $S_{1,i}$  to  $S_{7,i}$  in Table 1a and  $V_{1,i}$  to  $V_{7,i}$  in Table 1b arranged at the second row from above denoted by \*F1 in the leftmost column are set values set before the strip thickness change point reaches the F1 stand.

In Fig. 1, a rolling mill driver unit 20 includes a plurality of motors for driving the respective stands for constituting the rolling mill 10 and a speed controller for controlling the respective motor speeds at designated values, respectively. The roll gap control unit 21 provided for the rolling mill 10 controls the roll gaps of the respective stands to the respective designated values. Further, a flying gage change control unit 22 provided for the same rolling mill 10 is composed of a set value calculating section 23 and a rolling mill control section 24.

The set value calculating section 23 decides a coil pass schedule of the succeeding rolled coil; that is, the respective stand outgoing side strip thicknesses, the roll gap set values, the roll speed set values as listed in Tables 1a and 1b, and applies the decided coil pass schedule to the rolling mill control section 24. On the basis of the decided coil pass schedule, the rolling mill control section 24 tracks the strip thickness change point previously decided on the basis of a predetermined coil length, and applies the set value change rate obtained on the basis of data transferred from the set value calculating section 23, to the rolling mill driving unit 20 and the roll gap control unit 21, at such a timing that the strip thickness change point reaches the respective stand, respectively.

On the basis of the commands, the rolling mill driving unit 20 and the roll gap control unit 21 change the roller speed and the roll gap. As described above, the outgoing side strip thickness of the stand is changed from the  $i$ -th coil value to the  $(i+1)$ -th coil value in sequence. Further, when the strip thickness change point passes through the final stand, the rolling for the  $(i+1)$ -th coil ends.

After the outgoing side target strip thickness has been changed by the rolling mill 10, a cut-off point is set near the strip thickness change point (e.g., a one-meter behind the strip thickness change point). At a timing when this set cut-off point reaches the strip shear 11, the rolled strip is cut off, so that the (i+1)-th coil is coiled by a down coiler different from a down coiler for coiling the i-th coil.

A strip thickness (gage) change point tracking unit 26 decides the cut-off timing of the strip shear 11. That is, after the strip thickness change point has passed through the rolling mill 10, this tracking unit 26 calculates the strip thickness change point position from the final stand, by integrating the final stand outgoing side rolled strip speed with respect to time. Here, the final stand outgoing side rolled strip speed can be obtained by integrating the final stand outgoing side rolling strip speed can be obtained by a product of the final stand roll speed and the forward slip. The calculated strip thickness change point position is outputted to a strip shear control unit 27.

This strip shear control unit 27 detects the arrival of the previously decided cut-off point at the strip shear 11 on the basis of the output of the strip thickness (gage) change point tracking unit 26, and starts the strip shear 11 to cut off the rolled strip.

In this first embodiment, since the head threading-work is required for the first coil, the strip thickness of the first coil is determined relatively thick (e.g., 20 mm). However, it is possible to easily roll a thin strip less than 1 mm, by changing the strip thickness of the rolled strip, under rolling conditions.

In other words, when the flying gage change is applied, it is possible to realize a versatile production plan. In addition, since the strip head threading work and plate tail-out work (which often cause the off-gage trouble) can be both reduced, with the result that the rolling productivity can be improved.

By the way, in order to further increase the productivity, it is effective to increase the slab thickness as already explained. However, when the slab thickness is increased, two rolling mill such as the roughing mill and the finishing mill are both necessary, as shown in Fig. 7, due to the rolling capacity of the rolling mill.

A second embodiment of the hot strip mill for realizing the hot rolling method according to the present invention will be described hereinbelow with reference to Fig. 4. In this embodiment, the line length is shortened by reducing the distance between the roughing mill and the finishing mill, as shown in Fig. 4 in which the same reference numerals have been retained for similar elements or units having the same functions as with the case of the first embodiment, without repeating the similar description.

In Fig. 4, the slab manufactured by a continuous casting installation 7 is fed to a slab heating installation 14 without being cut off and further, after having been heated to a predetermined slab temperature, conveyed to a roughing mill 12. The roughing mill 12 is composed of a vertical rolling mill for rolling the slab in the width direction and a horizontal rolling mill for rolling the slab in the thickness direction. The roughing mill 12 is used to roll the slab only in one direction, the number of the rolling mill for constituting the roughing mill 12 is determined on the basis of the required rolling capacity. In the case of the mill shown in Fig. 4, since the slab having a thickness of 150 mm is assumed, one vertical rolling mill and two horizontal rolling mill are shown. The slab is rolled by the roughing mill 12 to a predetermined thickness (e.g., 50 mm) and then conveyed to a finishing mill 13. After having been rolled to a target thickness by the finishing mill 13, the slab is cooled by a rolled strip cooling installation 5 down to a predetermined temperature, and after that coiled by a down coiler 6.

When the weight or the length of rolled strip being coiled reaches a predetermined value, the rolled strip is cut off by a strip shear 11 installed on the incoming side of the down coiler. Further, the rolled strip on the rolling mill side is conveyed to another down coiler and then coiled.

Here, the bar length is considered. When the slab manufactured by the continuous casting installation at one time is assumed to be 150 ton in weight, 1000 mm in bar width, and 50 mm in bar thickness, the bar length is about 380 m. Therefore, it is not advantageous from the space standpoint to increase the space between the roughing mill and the finishing mill as long as the bar length, from the installation space. Therefore, in this second embodiment shown in Fig. 4, the roughing mill and the finishing mill are arranged close to each other to such an extent that a space for a crop shear or a scale breaker can be secured. In other words, since the rolled plate can be rolled by both the rough and finishing rolling mill at the same time, it is possible to shorten the production line length and reduce the equipment cost thereof, which is another feature of the present invention.

In addition, when the flying gage (bar-thickness) change function of the roughing mill and the flying gage (strip thickness) change function of the finishing mill are both provided, it is possible to increase the adaptability to various production schedules.

In Fig. 4, a roughing mill driving unit 28 provided for the roughing mill 12 is composed of motors for driving the stands for constituting the roughing mill 12 and a speed control unit for controlling the motor speeds to designated values, respectively. Further, a roughing mill roll gap control unit 29 provided for the roughing mill 12 controls the roll gaps of the horizontal rolling mill for constituting the roughing mill 12 to designated values, respectively. In the same way, a finishing mill driving unit 30 provided for the finishing mill 13 is composed of motors for driving the stands for constituting the finishing mill 13 and a speed control unit for controlling the motor speeds to designated values, respectively. Further, a finishing mill roll gap control unit 31 provided for the finishing mill 13 controls the roll gaps of the horizontal rolling mill for constituting the finishing mill 13 to designated values, respectively.

Further, a flying gage change control unit 33 provided for controlling the roughing mill driving unit 28 and the finishing mill driving unit 30 executes the bar thickness change control by changing the roll gap set values and the roll speed set values of the rough rolling machine 12 and further the target thickness change control by changing the roll gap set values and the roll speed set values of the finishing mill 13.

As described above, in this second embodiment, since the rough rolling machine 12 and the finish strip mill 13 are installed close to each other, the bar can be rolled at such a state as to extending between the roughing mill and the finishing mill. Therefore, the bar thickness can be changed by the roughing mill 12 under rolling condition, and further the strip thickness can be changed by the finishing mill 13 also under rolling conditions, in the same way as with the case of the first embodiment shown in Fig. 1.

In more detail, a set value calculating section 34 for constituting a flying gage change control unit 33 calculates the roll gap set values and the roll speed set values for executing the flying gage change (similar to the set values as listed in Tables 1a and 1b) on the basis such a consideration that the roughing and finishing mills constitute one rolling mill. The calculated set values are outputted to a rolling mill control section 35.

On the other hand, a slab length measuring unit 36 measures the slab length, immediately after the top end of the slab is engaged with the first horizontal rolling mill for constituting the roughing mill 12, to detect a timing at which a slab thickness change point reaches the first horizontal rolling mill. The detected timing signal is outputted to the rolling mill control section 35.

At this timing when the strip thickness change point reaches the first stand of the roughing mill, the rolling mill control section 35 gives the set value change command decided on the basis of the set values of the set value calculating section 34, to the roughing mill driving unit 28 and the roughing mill roll gap control unit 29, in order to change the roll gap set value and the roll speed set value of the first stand. Further, at the timings when the strip thickness change point reaches another stand of the roughing mill and the respective stands of the finishing mill 13, the rolling mill control section 35 outputs the set value change commands to the rough rolling machine driving unit 28, the roughing mill roll gap control unit 29, the finishing mill driving unit 30 and the finishing mill roll gap control unit 31 respectively, in order to change the roll gap set values and the roll speed set values of the corresponding stands.

On the basis of the above operation, the strip thickness on the outgoing side of the finishing mill can be changed.

Further, the rolled strip is cut off at a predetermined cut-off position by the strip shear 11 on the basis of commands applied by a strip thickness change point tracking unit 26 and a strip shear control unit 27, in the same way as with the case of the first embodiment shown in Fig. 1.

By use of the second embodiment as shown in Fig. 4, it is possible to easily roll a thin rolled strip less than 1 mm, while improving the productivity, because the head threading work and the tail-out work can be both reduced. As a result, a versatile production plan can be scheduled.

In the above description, although the change of the bar thickness and the target strip thickness of the finishing mill have been explained, in the case where the bar thickness is not required to be changed or where the bar thickness cannot be changed, it is a matter of course that only the target strip thickness of the finishing mill is changed, without changing the bar thickness.

By the way, when the flexibility of the production schedule is considered, it is very advantageous that coils of different strip widths can be rolled continuously. For this purpose, the following method can be considered: the roll opening rate of the vertical rolling mill for constituting the second embodiment shown in Fig. 4 is changed under rolling conditions, in such a way that coils of different strip widths can be produced from the same slab by changing the bar width. In this case, in order to obtain a target strip width change rate, the bar width change rate and the roll opening rate change rate of the vertical rolling mill can be calculated on the basis of the well-known rolling theory.

A third embodiment of the hot strip mill for realizing the hot rolling method according to the present invention will be described hereinbelow with reference to Fig. 5, in which the same reference numerals have been retained for similar elements having the same functions as with the case of the second embodiment shown in Fig. 4.

As shown in Fig. 5, a rough strip mill 12 is composed of a vertical rolling mill and two horizontal rolling mill 16 and 17. The vertical rolling mill 15 rolls a slab in the width direction thereof by a pair of vertical rolls. Here, the roll opening rate can be controlled on the basis of a value designated by the vertical rolling mill roll opening rate control unit 37.

A flying bar width change control unit 38 provided for controlling a vertical rolling mill roll opening rate control unit 37 is composed of a set value calculating section 39 and a rolling mill control section 40. Further, the set value calculating section 39 calculates a bar width by correcting a target strip width of a coil rolled by the roughing mill at the succeeding stage under due consideration of the width fluctuation rate during rolling by the finishing mill (which can be obtained on the basis of the target mill thickness or the bar thickness), and further calculates the outgoing side width of the vertical rolling mill by correcting the width fluctuation rate during rolling by the horizontal rolling mill 16 and 17. On the basis of the calculated width, the vertical rolling mill opening rate is decided, and the decided opening rate is applied to a rolling mill control section 40.

A slab length measuring unit 41 connected to the rolling mill control section 40 starts measuring the slab length at a timing when the slab end is engaged with the vertical rolling mill 15, and transmits a timing signal to the rolling mill control section 40 by detecting a timing when the strip thickness change point reaches the vertical rolling mill 15. On

the basis of this timing, the rolling mill controls section 40 transmits a set value change command to a vertical rolling mill roll opening rate control unit 37 on the basis of a vertical rolling mill roll opening rate set value applied by a set value calculating section 39, in order to change the outgoing side slab width of the vertical rolling mill. Therefore, the outgoing side bar width of the roughing mill 12 and the outgoing side strip width of the finishing mill 13 can be both changed under rolling conditions.

As described above, in the third embodiment shown in Fig. 5, since the coils of different strip widths can be produced from the same slab, it is possible to attain a versatile production schedule with a high productivity.

Further, in the above description, although only the change of the strip width has been explained, it is of course possible to combine both the strip width change with the strip thickness change as explained with reference to Fig. 4.

As described above, in the hot rolling method or apparatus according to the present invention, since the slab manufactured by the continuous casting installation can be directly rolled, the consumption rate of heat energy can be reduced. Further, since the coils are manufactured by cutting off the rolled slab, the rolling time can be reduced, with the result that it is possible to attain a high productivity while saving energy. In addition, when the flying gage (strip thickness) change function and the flying gage (bar thickness) change function are both added to the rolling mill, it is possible to cope with various production schedules, to improve the rolling work efficiency, and to enable a thin strip rolling as thin as less than 1 mm easily.

## Claims

1. A hot strip mill having at least a continuous casting installation, a rolled strip heating installation, a rolling mill, a strip shear, and a down coiler, all being arranged in sequence, for keeping warm or heating a rolled strip manufactured through the continuous casting installation by the rolled strip heating installation, for rolling the heated rolled strip to a target strip thickness by the rolling mill, for coiling the rolled strip by the down coiler, and for cutting off the coiled rolled strip into a predetermined length by the strip shear, which comprises:

a rolled plate length measuring unit for measuring a length beginning from a top end of the rolled strip going out of the rolled strip heating installation, and outputting a timing signal when a strip thickness change point previously determined on the rolled strip reaches the rolling mill;

a flying gage strip change control unit including:

a set value calculating section for calculating a roll gap set value and a roll speed set value of the rolling mill; and

a rolling mill control section for changing a roll gap set value and a roll speed set value of the rolling mill, under rolling conditions, on the basis of the roll gap set value and the roll speed set value both calculated by said set value calculating section and in response to the timing signal outputted by said rolled strip length measuring unit;

a strip thickness change point tracking unit for detecting a strip thickness change point position on an outgoing side of the rolling mill; and

a strip shear control unit for cutting off the rolled strip by the strip shear according to the output of said strip thickness change point tracking unit, in order to manufacture coils of different strip thicknesses continuously from the same rolled plate.

2. A hot strip mill having at least a continuous casting installation, a rolled strip heating installation, a roughing mill, a finishing mill, a strip shear, and a down coiler, all being arranged in sequence and further the roughing and finishing mills being arranged close to each other, for keeping warm or heating a rolled strip manufactured through the continuous casting installation by the rolled strip heating installation, for rolling the heated rolled strip to a bar having a target thickness by the roughing mill and further continuously rolling the rolled bar to a target strip thickness by the finishing mill, for coiling the rolled strip by the down coiler, and for cutting off the coiled rolled strip into a predetermined length by the strip shear, which comprises:

a rolled strip length measuring unit for measuring a length beginning from a top end of the rolled strip going out of the rolled strip heating installation, and outputting a timing signal when a strip thickness change point previously determined on the rolled strip reaches the rough rolling mill;

a flying gage change control unit including:

a set value calculating section for calculating a roll gap set value and a roll speed set value of the roughing mill and a roll gap set value and a roll speed set value of the finishing mill, respectively; and

a rolling mill control section for changing a roll gap set value and a roll speed set value of each of the roughing and finishing mills, under rolling conditions, on the basis of the roll gap set values and the roll speed set values both calculated by said set value calculating section and in response to the timing signal outputted by said rolled strip length measuring unit;

a strip thickness change point tracking unit for detecting a strip thickness change point position on an outgoing side of the finishing mill; and

a strip shear control unit for cutting off the rolled strip by the strip shear according to the output of said strip thickness change point tracking unit, in order to manufacture coils of different strip thicknesses continuously from the same rolled plate.

3. The hot strip mill of claim 3, wherein:

the roughing mill comprises a vertical rolling mill for rolling the rolled strip in a width direction thereof, and a horizontal rolling mill for rolling the rolled strip in a thickness direction thereof;

said rolled strip length measuring unit measures a length beginning from a top end of the rolled strip going out of the rolled strip heating installation, and further detects a timing at which the previously determined strip thickness change point reaches the vertical rolling mill; and

which further comprises a flying bar width control unit including:

a set value calculating section for calculating a roll opening rate set value of the vertical rolling mill in order to change a bar width at the strip thickness change point; and

a rolling mill control section for changing a roll opening rate of the vertical rolling mill, under rolling conditions, on the basis of the vertical rolling mill roll opening rate set value calculated by said set value calculating section and in response to the timing outputted by said rolled strip length measuring unit, in order to manufacture a plurality of coils of different strip thicknesses and/or different strip widths continuously from the same rolled plate.

4. A hot rolling method, comprising the steps of:

arranging at least a continuous casting installation, a tunnel furnace, a rolling mill, a strip shear, and a down coiler in sequence;

keeping warm or heating a single rolled strip manufactured through the continuous casting installation by the tunnel furnace;

rolling the rolled strip taken out of the tunnel furnace to a target strip thickness by the rolling mill;

coiling the rolled strip by the down coiler;

cutting off the rolled strip plural times so that the coiled rolled strip becomes a predetermined length;

changing a target strip thickness on the outgoing side of the rolling mill, under rolling conditions, in order to manufacture a plurality of coils of different strip thicknesses from the same rolling plate.

5. A hot rolling method, comprising the steps of:

arranging at least a continuous casting installation, a tunnel furnace, a roughing mill, a finishing mill, a strip shear, and a down caller in sequence, the roughing and finishing mills being arranged close to each other;

keeping warm or heating a single rolled strip manufactured through the continuous casting installation by the tunnel furnace;

rolling the rolled strip taken out of the tunnel furnace to a bar having a target thickness by the roughing mill;

continuously rolling the bar to a target strip thickness by the finishing mill;

coiling the rolled strip by the down coiler;

cutting off the rolled strip plural times so that the coiled rolled strip becomes a predetermined length;

changing the bar thickness of the roughing mill and/or changing the target strip thickness of the finishing mill, under rolling conditions, in order to manufacture a plurality of coils of different strip thicknesses from the same rolling plate.

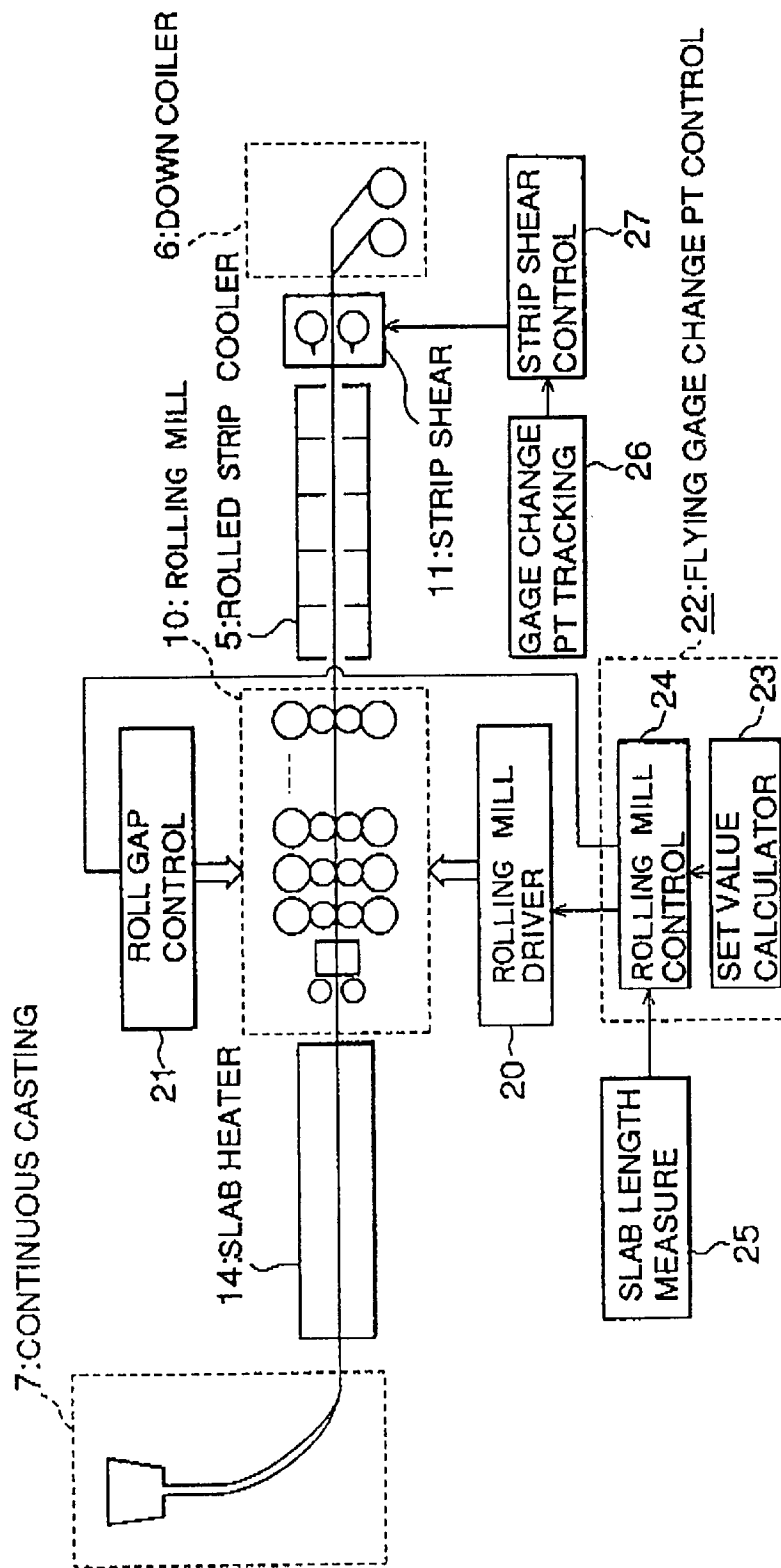


FIG.1

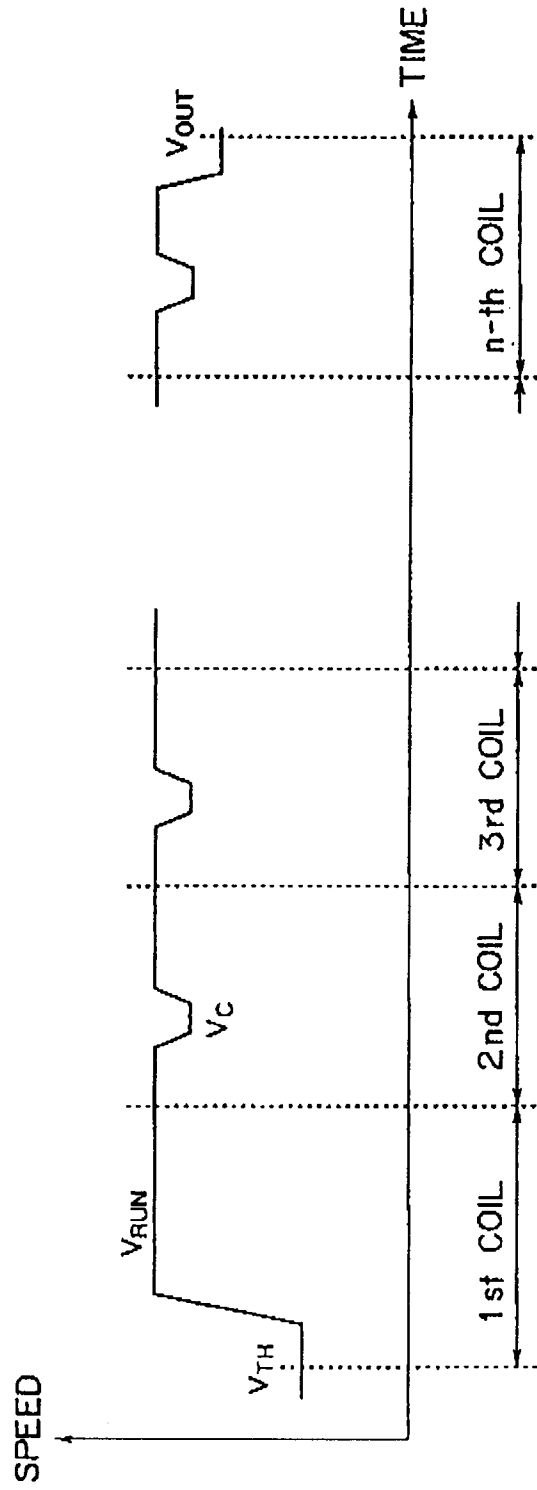


FIG. 2

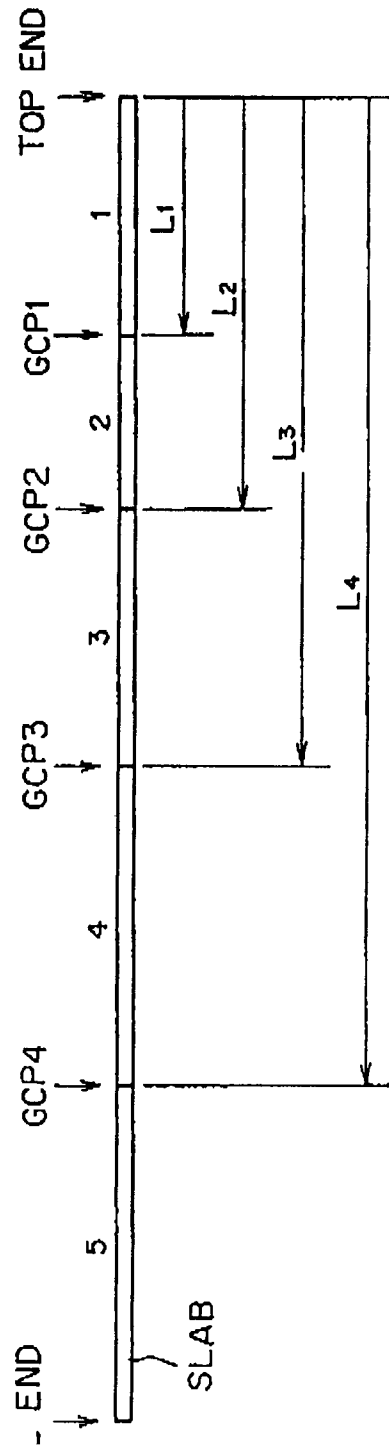


FIG. 3

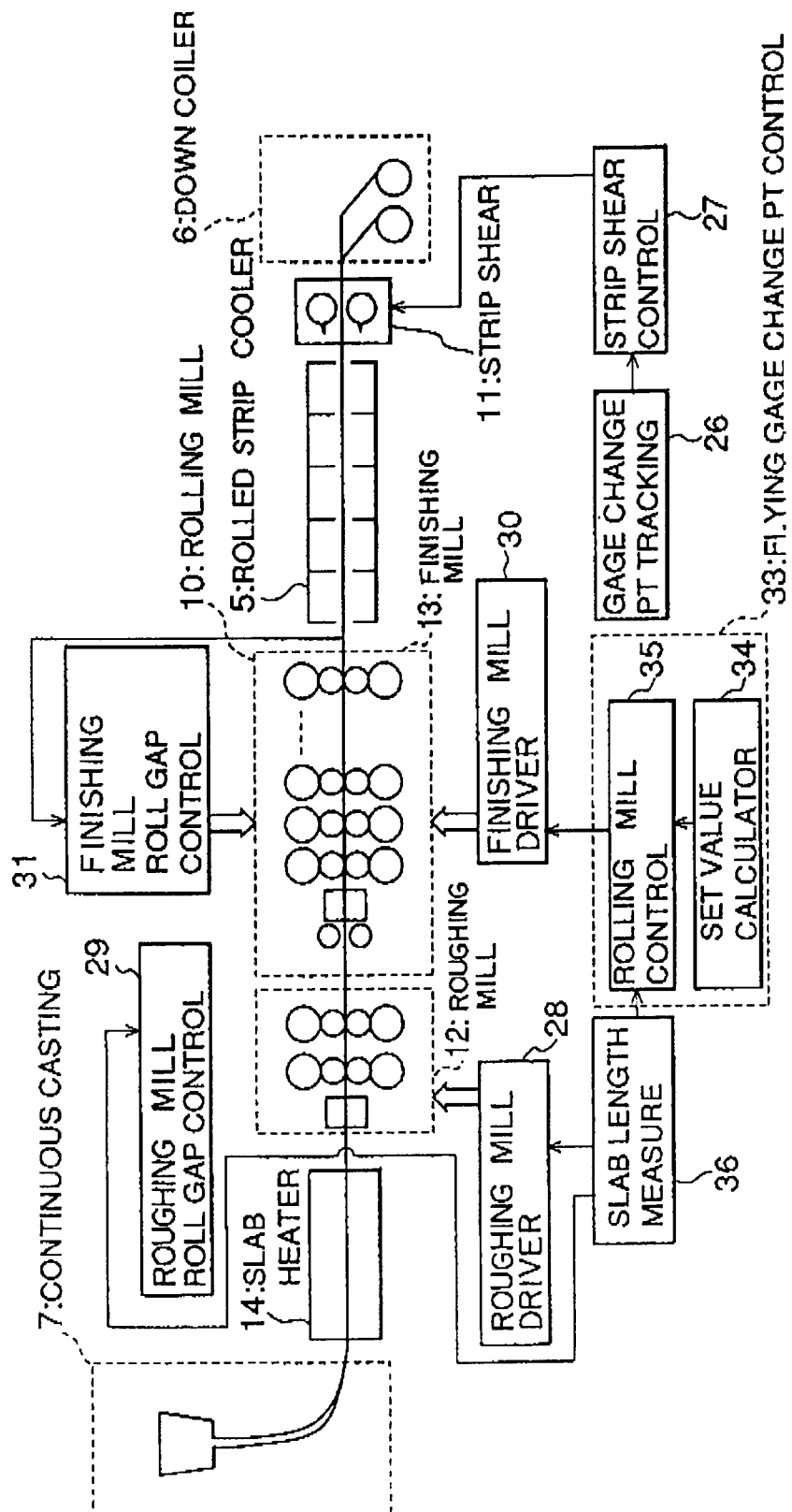


FIG.4

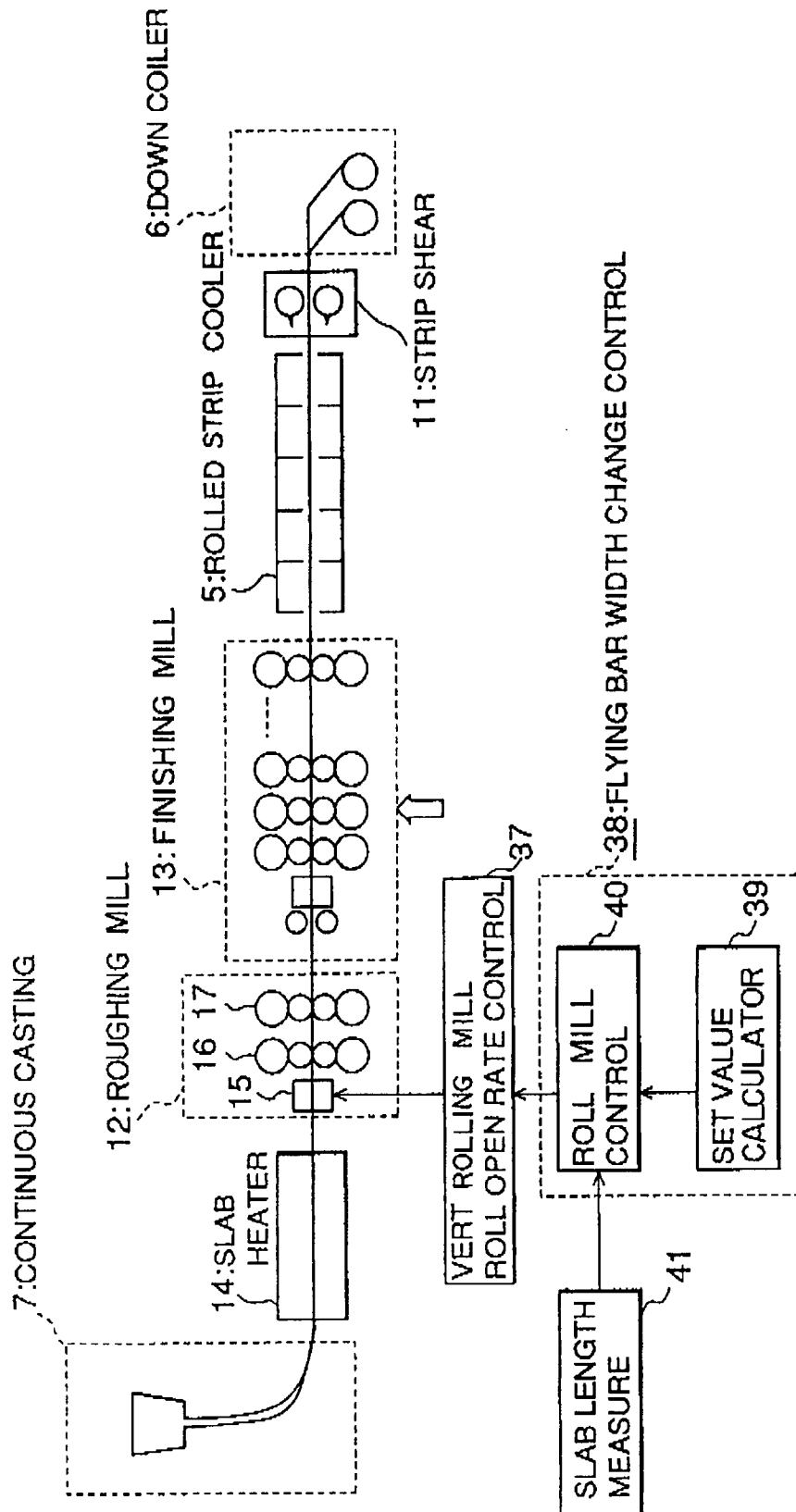


FIG.5

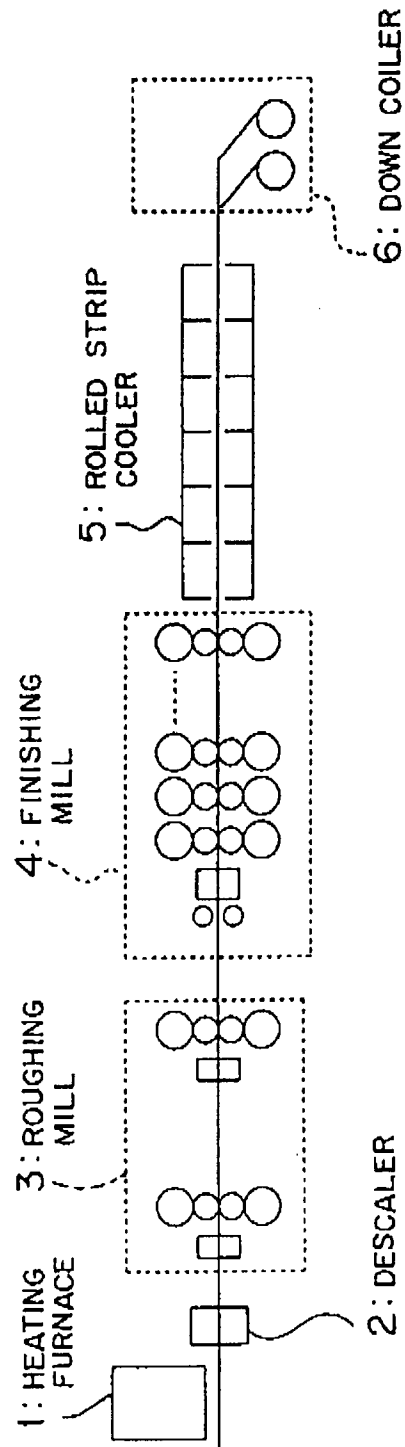


FIG. 6  
PRIOR ART

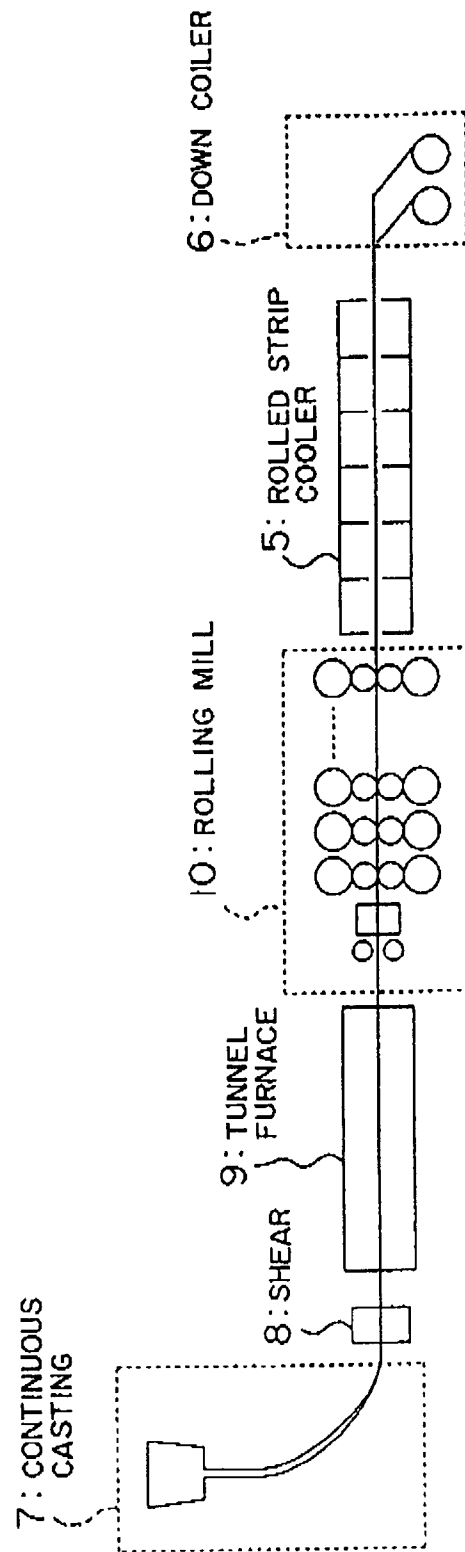


FIG. 7  
PRIOR ART

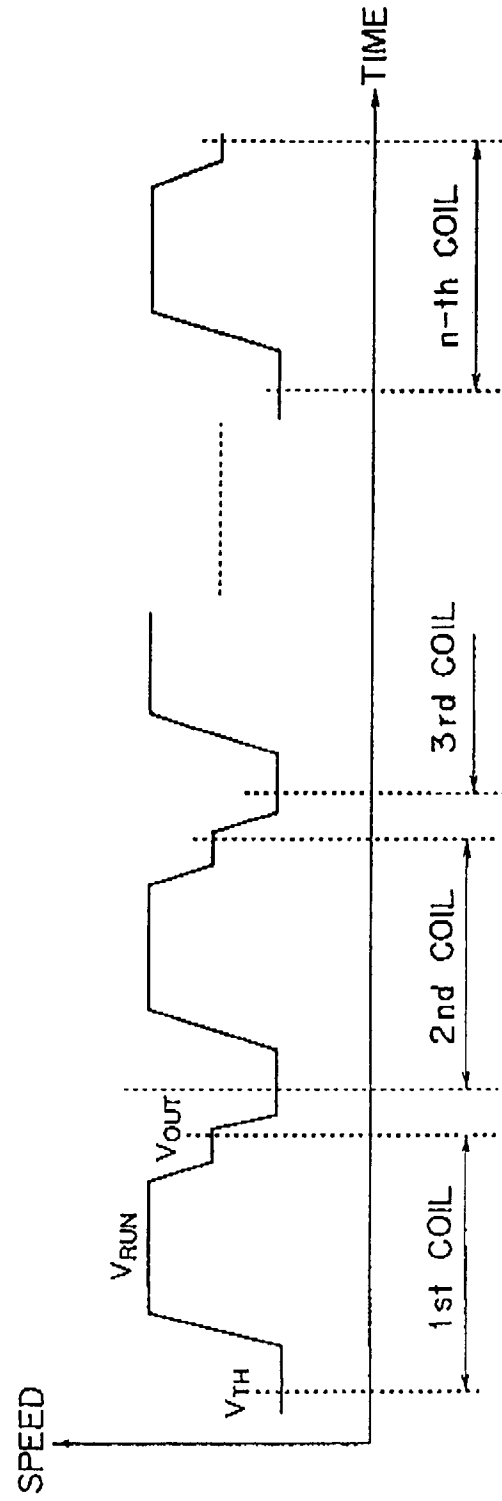


FIG. 8



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# EUROPEAN SEARCH REPORT

Application Number  
EP 96 10 3339

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                     |                                                                                                                                                               |                                                                                                                                                                                                                                                                              |                                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Category                                                                                                                                                                                                                | Citation of document with indication, where appropriate, of relevant passages                                                                                 | Relevant to claim                                                                                                                                                                                                                                                            | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| X                                                                                                                                                                                                                       | PATENT ABSTRACTS OF JAPAN<br>vol. 8, no. 210 (M-328), 26 September 1984<br>& JP-A-59 097705 (HITACHI)                                                         | 4,5                                                                                                                                                                                                                                                                          | B21B37/26                                    |
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| A                                                                                                                                                                                                                       | ---                                                                                                                                                           | 3                                                                                                                                                                                                                                                                            |                                              |
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|                                                                                                                                                                                                                         | ---                                                                                                                                                           |                                                                                                                                                                                                                                                                              |                                              |
|                                                                                                                                                                                                                         | -/--                                                                                                                                                          |                                                                                                                                                                                                                                                                              |                                              |
| The present search report has been drawn up for all claims                                                                                                                                                              |                                                                                                                                                               |                                                                                                                                                                                                                                                                              |                                              |
| Place of search                                                                                                                                                                                                         |                                                                                                                                                               | Date of completion of the search                                                                                                                                                                                                                                             | Examiner                                     |
| THE HAGUE                                                                                                                                                                                                               |                                                                                                                                                               | 21 June 1996                                                                                                                                                                                                                                                                 | Plastiras, D                                 |
| CATEGORY OF CITED DOCUMENTS                                                                                                                                                                                             |                                                                                                                                                               |                                                                                                                                                                                                                                                                              |                                              |
| X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |                                                                                                                                                               | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                              |

EPO FORM 1503 03.82 (P04C01)



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 96 10 3339

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                |                                  |                                              |
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| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                  | Relevant to claim                | CLASSIFICATION OF THE APPLICATION (Int.Cl.6) |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | PATENT ABSTRACTS OF JAPAN<br>vol. 11, no. 269 (M-621), 2 September 1987<br>& JP-A-62 072415 (KAWASAKI), 3 April 1987,<br>* abstract *<br>----- | 1-5                              |                                              |
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| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                |                                  |                                              |
| Place of search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                | Date of completion of the search | Examiner                                     |
| THE HAGUE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                | 21 June 1996                     | Plastiras, D                                 |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                |                                  |                                              |

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