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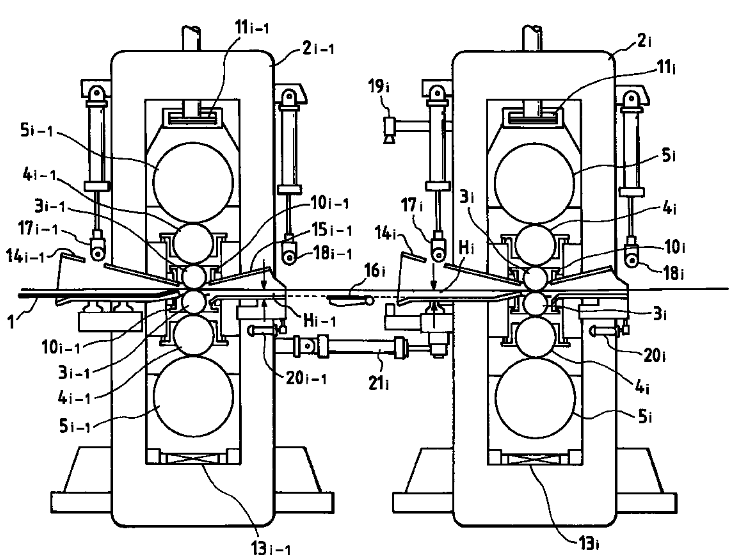
(57) Disclosed is a hot strip mill plant for preventing a failure in biting of a plate material (1) at small diameter work rolls (3). An inlet side plate passing guide (14) and an outlet side plate passing guide (15) for guiding the plate material (1) between the work rolls (3) are provided on the inlet and outlet sides of a rolling mill. The advancing plate material (1) is deflected upward by a reaction force. Hold-down rollers (17,18) capable of being ascended/descended for preventing the floating of the plate material are provided, and thereby the plate material receives a press-in force larger than the reaction force of the work rolls (3) by the hold-down rollers (17,18). As a result, the plate material is certainly bitten between the work rolls (3). Moreover, a roll balance force or roll bending force for the work rolls is controlled upon biting of the plate material for transmitting a torque necessary for the work rolls, thereby increasing contact forces between the work rolls (3) and intermediate rolls (4).

FIG. 1



EP 0 745 440 A1

Description

BACKGROUND OF THE INVENTION

The present invention relates to a compact hot strip mill plant capable of producing a hot strip at a rolling speed in match with an output while improving energy saving, and a rolling method of the same.

A related art typical hot strip mill plant is known from a reference "Recent Hot Strip Manufacturing Technique in Japan" (Iron and Steel Association of Japan, pp. 176 and 305-310, August 10, 1987), which describes a high speed/large scale rolling plant exhibiting an output of from 3 to 4 million tons/year and a finishing rolling speed of from 680 to 1627 m/mim. In this rolling plant, a roughing rolling mill for rolling down a slab having a thickness of 200 mm into a bar having a thickness of from 20 to 40 mm adopts a work roll having a diameter of from 1000 to 1300 mm; and a finishing rolling mill for rolling down a bar having a thickness of from 20 to 40 mm into a strip having a thickness of 12 mm or less adopts a work roll having a thickness of from 600 to 800 mm.

Incidentally, the recent development of a thin slab continuous casting method realizes a slab having a thickness of about 50 mm. Such a thin slab eliminates the use of a roughing rolling mill and requires only a finishing rolling mill. The production system using the thin slab has been first applied to a small-scale production, as shown in a reference "Ein Jahr Betriebserfahrung mit der CSP-Anlage fuer Warmbereitband bei Nucor Steel" (Stahl u. Eisen 111 (1991) Nr. 1). The above production system using a thin slab follows the related art system including finishing rolling mills of 5 to 7 stands despite the output is only 0.7 million tons/year. Specifically, the rolling speed at the outlet of the finishing rolling mill is 300 m/min or more for a finishing thickness of 2.5 mm and 600 m/min or more for a thickness of 1.6 mm. Also, the diameter of a work roll used for the fining rolling mill follows the related art size, that is, from 760 to 800 mm.

On the other hand, Japanese Patent Laid-open No. Hei 6-320202 discloses a merit in use of small diameter work rolls from the viewpoint of a relationship between a necessary output and the maximum rolling speed of a rolling mill plant or energy saving, and it proposes a production system on the basis of the new concept. Fig. 2 is a view showing comparison in necessary energy between work rolls having diameters of 800 mm and 360 mm of a fining rolling mill in the case of rolling a slab of 200 mm thick into a hot strip of 2 mm thick. As seen from this figure, it becomes apparent that the small diameter roll is effective for energy saving.

The technique described in Japanese Patent Laid-open No. Hei 6-320202 basically uses small diameter work rolls for finishing after-stage stands occurring no problem in biting, and it adopts an indirect drive system in which the work rolls are driven through intermediate rolls or back-up rolls for preventing temperature drop of a material to be rolled due to a strong reduction by the small diameter work rolls. Also, this patent is intended to enhance energy saving by improvement in deforming efficiency of a material to be rolled by the use of the small diameter work rolls.

Japanese Patent Laid-open No. Sho 54-149356 describes a rolling mill plant including a device for vertically restricting the rear end of a loop-shaped curved portion generated at the leading end portion of a material to be rolled when the leading end of the material is butted to the rolls and preventing reversed movement of the material, and vertically pressing the loop-shaped curved portion and moving forward the leading end of the material, thereby allowing the material to be bitten in a roll gap.

The use of the small diameter work rolls described in Japanese Patent laid-open No. Hei 6-320202 is limited by the biting, and if the small diameter work rolls are applied to the finishing before-stage stands, the reduction ratio is necessarily limited. Accordingly, in the rolling mill plant described in this patent, when the small diameter work rolls are adopted for a finishing first stand, a leading end thinning device for reducing the thickness of the leading end of the plate material before rolling is provided.

The use of small diameter work rolls is also limited in terms of transmission of a torque by a spindle, and thereby the small diameter work rolls are often indirectly driven through intermediate rolls or back-up rolls. In this case, a friction coefficient more than a value necessary for biting is required to be imparted between work rolls and intermediate rolls or back-up rolls. However, in the real rolling, this cannot be perfectly guaranteed because of the possibility of slip between the rolls.

On the other hand, a hot-rolling oil having an effect to reduce a friction coefficient between a plate and a work roll and hence to reduce a rolling load and a rolling power has been not sufficiently applied even on a large diameter work rolls depending on the biting condition. Accordingly, the effect of a hot-rolling oil or a roll lubricant cannot be fully used.

The reversed movement preventive device and the loop pressing device described in Japanese Patent Laid-open No. Sho 54-149356 vertically restrict a material to be rolled. To restrict the material to be rolled, the material must be stopped on the inlet side of the rolling mill. As a result, such devices can be used only for a cold rolling plant having an apparatus for storing the material or a single stand rolling mill repeating several rolling steps. In other words, the devices cannot be used for the case of rolling a plate material continuously produced from a continuous casting machine, that is, the case of a tandem rolling using a plurality of rolling mills.

SUMMARY OF THE INVENTION

In view of the foregoing, the present invention has been made, and an object of the present invention is to provide a rolling mill plant capable of enhancing productivity in rolling and improving energy saving.

To achieve the above object, according to a preferred mode of the present invention, there is provided a hot strip mill plant for rolling a plate to be hot-rolled using a plurality of rolling mills each including work rolls, the rolling mill including the work rolls including: plate passing guide members each being provided in such a manner as to be sloped and to vertically surround a pass line of the plate; and rollers each capable of being ascended/descended to a desired position for holding-down a floating of the plate and provided near each of the plate passing guide members.

With this configuration, in the case of rolling a plate to be hot-rolled using a rolling mill including small diameter work rolls, the plate guided between the small diameter work rolls by the plate passing guide members provided in such a manner as to vertically surround the pass line, is deflected upward by a reaction force when bitten between the work rolls. At this time, the plate is held down by the rollers, each being provided near the plate passing guide members and capable of ascended and descended to a desirable position against the plate guided by the plate passing guide members, and it receives a press-in force larger than the reaction force of the work rolls by the rollers, to be thus bitten between the small diameter work rolls.

The above rolling mill preferably includes a roll balance device capable of imparting contact forces between small diameter work rolls and intermediate rolls.

With this configuration, the biting of the plate material at the small diameter work rolls can be suitably performed by positively transmitting a torque to the small diameter work rolls when the plate material is bitten between the work rolls.

According to another mode of the present invention, there is provided a four-stage rolling mill plant including rolling mills each having a pair of work rolls, a pair of back-up rolls, and a system for scattering a hot-rolling oil to the work rolls, the rolling mill having the work rolls including: plate passing guide members each being provided in such a manner as to vertically surround a pass line of a plate material; and rollers each capable of being ascended/descended to a desirable position for holding down a floating of the plate and provided near each of the plate passing guide members; wherein the plate material is introduced between the work rolls while the hot-rolling oil is scattered on the work rolls.

With this configuration, the advance of a plate to be hot-rolled is restricted by the plate passing guide members for guiding the plate between the work rolls on which a hot-rolling oil is scattered and hold-down rollers for holding-down the plate, and a press-in force larger than the reaction force of the work rolls is applied to the plate. As a result, the plate can be bitten between the work rolls even in the state in which the hot-rolling oil is continuously scattered.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of an (i-1)-th stand and an i-th stand of a six-stage rolling mill plant showing a plate passing state (the moment of biting in the (i-1)-th stand);

Fig. 2 is a graph showing an energy saving effect of a small diameter roll in hot rolling;

Fig. 3 is a graph showing a relationship between a press-in force for a material to be rolled and a reduction thereof;

Fig. 4 is a graph showing a relationship between a floating height due to buckling of a plate and a press-in force upon biting of the plate;

Fig. 5 is a graph showing a relationship between a friction coefficient between rolls and a roll balance force necessary for preventing generation of a slip between the rolls upon biting of a plate in the case where the rolls are indirectly driven;

Fig. 6 is a sectional view of an (i-1)-th stand and an i-th stand of a four-stage mill plant showing a plate passing state;

Fig. 7 is a sectional view of an (i-1)-th stand and an i-stand of a six-stage rolling mill plant showing a plate passing state (after the biting in the (i-1)-th stand and before the biting in the i-th stand);

Fig. 8 is a sectional view of the (i-1)-th stand and the i-stand of the six-stage rolling mill plant showing a plate passing state (after the biting in the (i-1)-th stand and before the biting in the i-th stand);

Fig. 9 is a sectional view of the (i-1)-th stand and the i-stand of the six-stage rolling mill plant showing a plate passing state (the moment of the biting in the i-th stand);

Fig. 10 is a sectional view of the (i-1)-th stand and the i-stand of the six-stage rolling mill plant showing a plate passing state (after the biting in the (i-1)-th stand and in the i-th stand);

Fig. 11 is a flowchart showing control of rolls for restricting the pass of a material to be rolled upon biting;

Fig. 12 is a flowchart showing control of a roll balance force upon biting in an indirect driven mill;

Fig. 13 is a sectional view of the (i-1)-th stand and the i-th stand of the six-stage mill plant showing a roll changing state (after the biting in the (i-1)-th stand and the i-th stand);

Fig. 14 is a sectional view of an (i-1)-th stand and an i-th stand of a four-stage mill plant in which a hot-rolling oil is used;

Fig. 15 is a view showing a pair-cross type mill;

Fig. 16 is a view showing a work roll cross type mill;
Fig. 17 is a view showing a guitar-like roll type mill; and
Fig. 18 is a view showing a cluster mill.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Hereinafter, the basic concept of the present invention will be described by way of a rolling mill using small diameter work rolls.

The principal problem occurring in the use of small diameter work rolls is biting of a plate to be rolled.

A biting reduction Δh in rolling is given by

$$\Delta h = \mu \times 2R - P/K \qquad (1)$$

where R = roll radius
P = rolling load
K = mill rigidity
μ = friction coefficient between roll and plate

Accordingly, as the roll radius R is made smaller, the biting reduction Δh becomes smaller, resulting in a failure in biting.

The biting reduction is also determined by a horizontal balance between a force drawing a plate in a roll bite and a rolling reaction force pressing back the plate.

A horizontal press-back force $F\theta$ applied to a plate in a state in which the plate is bitten to a degree of from a biting angle θ_O to an angle θ at the position of the leading end of the plate is given by

$$F\theta = B \times km \times R \times (\theta_O - \theta)\{(\theta_O - \theta)/2 - \mu\} \qquad (2)$$

where B: plate width
km: restrictive average deformation resistance
R: radius of work roll

If μ is larger than $(\theta_O-\theta)/2$ in this equation, $F\theta$ becomes negative. In this case, the plate tends to be drawn between the rolls. On the other hand, if μ is smaller than $(\theta_O-\theta)/2$, the plate is pressed-back. $F\theta$ is such a press-back force. Accordingly, even in the case where the roll radius is small or a friction coefficient is small, the biting can be realized by giving to the plate an external force larger than the press-back force $F\theta$.

Letting F be a press-in force necessary for pressing a plate to be rolled on the rolling mill side, the reduction Δh is expressed from the equation (2) as follows:

$$\Delta h = R \times [\mu + \sqrt{\{2F/(B \times km \times R)\}}] \times 2 - P/K \qquad (3)$$

where R: roll radius
μ: friction coefficient between roll and plate
B: plate width
km: restrictive average deformation resistance

Fig. 3 shows a biting reduction with the value of F changed from 0 to 10 tons on the assumption that R = 230 mm, μ = 0.25, B = 1200 mm, and km = 10 kg/mm^2. As seen from Fig. 3, the biting reduction can be increased by increasing the press-in force.

In general, an edger or a rolling mill is disposed in the before-stage of a rolling mill using small diameter work rolls, and a press-in force applied by the edger or the rolling mill is equal to the total of a buckling force of a plate to be rolled which is buckled in the width direction and a force required for lifting the dead weight of the plate. The buckling force F1 for buckling the plate is given by

$$F1 = (1.5\pi) \times 2EI/Lo \times 2 \qquad (4)$$

Also, the force F2 required for lifting the dead weight of the plate is given by

$$F2 = 0.7022wLo \times 2/(a\pi \times 2) \qquad (5)$$

In the above equations (4) and (5), the characters E, I, Lo, w and "a" are:

- E: Young's modulus of plate
- I: second moment of area of plate
- Lo: distance between stands
- w: weight of plate per unit length
- a: 1/2 of floating height of plate

The press-in force F is expressed by

$$F = F1 + F2 \qquad (6)$$

Assuming that the plate width B = 1200 mm, plate thickness h = 10 mm, distance between stands Lo = 5500 mm, E = 7000 kg/mm^2, I = 83000 mm^4 and a = 20 mm, F1 and F2 are obtained as follows:

$$F1 = 0.513 \text{ ton}$$

$$F2 = 10.15 \text{ tons}$$

The press-in force F is thus obtained as follows:

$$F = F1 + F2 = 10.66 \text{ tons} \qquad (7)$$

Fig. 4 shows a relationship between the buckling height, that is, the floating height of a plate and a press-in force on the assumption that B = 1200 mm, H = 10 mm and L = 5500 mm. As seen from Fig. 4, a high press-in force can be obtained by lowering the floating height.

For example, assuming that the friction coefficient between a roll and a plate is 0.25, rolling load is 1500 tons, mill rigidity is 400 tons/mm, and roll radius is 230 mm, the biting reduction Δh becomes 10.6 mm from the equation (1). On the contrary, in the case where the biting reduction is increased from 10.6 mm to 20 mm using the roll having the same diameter, a press-in force of about 7 tons is required as shown in Fig. 3. In this case, as shown in Fig. 4, a press-in force more than 7 tons can be obtained by holding-down the floating height of the plate to a value of 60 mm or less. Even in the case of using the small diameter work rolls each having a diameter of 460 mm, a sufficient biting amount can be thus obtained by controlling the floating height of the plate. Next, a force for holding-down a plate when the floating height of the plate is controlled by a roll will be examined.

For example, in the case where a roll diameter is 460 mm and a biting reduction is 20 mm, the floating height of a plate is controlled at a value of 60 mm or less by a pressing roll. The hold-down force f is approximately given by

$$f = FH/(L/2) \qquad (8)$$

where H: height of loop
L: floating distance of plate

Letting H = 50 mm and L = 3000 mm, the hold-down force becomes 1/30 of the press-in force from the equation (8). In this way, the plate can be sufficiently bitten by a hold-down force which is very smaller than a press-in force.

On the other hand, in a rolling mill using small diameter work rolls, it is difficult to directly give a torque necessary for rolling to the work rolls. In other words, the work rolls must be indirectly driven through back-up rolls or intermediate rolls. In general, a rolling load is set to obtain a desired plate thickness on the assumption that the plate is sufficiently bitten between rolls. Namely, there is no problem in rolling for a normal portion on which a rolling load is applied; however, at the time of biting, a load and a torque are transiently applied, and consequently, even if a friction coefficient necessary for biting between the plate and the rolls is obtained, the same friction coefficient between the rolls is not necessarily obtained. As a result, in some case, there occurs a biting failure. Here, in the case where a rolling torque is transmitted to a plate by indirect drive, a transmission torque is a contact load between rolls multiplied by a friction coefficient between the rolls and a roll diameter. Also, a friction coefficient necessary for biting is substantially equal to a friction coefficient for transmitting a rolling torque necessary upon biting. Namely, in the case where the friction coefficient between rolls is low and thereby a necessary torque cannot be transmitted, the low friction coefficient can be compensated by increasing a contact load between a work roll and an intermediate roll or a back-up roll, thereby making it possible to give the necessary torque to the work roll.

Next, there will be examined an increase in transmission force by increasing a roll balance force in addition to a contact load generated by rolling, and increasing the contact load by the roll balance force.

Letting μr be a friction coefficient at the contact point between rolls, P be a rolling load, Fw be a roll balance force and R be a radius of a work roll, a transmission torque T1 by indirect drive is given by

$$T1 = \mu r(P + Fw)R \qquad (9)$$

On the other hand, letting μ be a friction coefficient between a plate and a roll, a torque Tr necessary for rolling is given by

$$Tr = \mu PR \qquad (10)$$

Here, when T1>Tr, the plate can be bitten. From the equations (9) and (10), the following equation is given:

$$\begin{aligned} T1 - Tr &= \mu r(P + Fw)R - \mu PR \\ &= PR(\mu r - \mu) + \mu rFwR > 0 \end{aligned}$$

Consequently, the roll balance force Fw is

$$Fw > P(\mu - \mu r)/\mu r = P\ (\mu/\mu r - 1) \qquad (11)$$

Here, the rolling load P differs in accordance with the degree of biting of the plate. Letting Po be a rolling load at a normal portion, θo be a biting angle and θ be an angle at the present position of the leading end of the plate, the rolling load P is given by

$$P = Po(\theta o - \theta)/\theta o \qquad (12)$$

From the equations (11) and (12), the roll balance force Fw becomes

$$Fw > Po(1 - \theta/\theta o)/(\mu/\mu r - 1) \qquad (13)$$

Moreover, the necessary press-in force is maximized upon $\theta = \mu r$ by balance of the horizontal force of the plate in a roll bite. As a result, with the substitution $\theta = \mu r$ and $\theta o = 0$, the equation (13) can be rearranged as follows:

$$\begin{aligned} Fw &> Po(\mu - \mu r)(\mu - \mu r)/(\mu/\mu r) = B\times km\times R\times\mu(\mu - \mu r)\times 2/(\mu/\mu r) \qquad (14) \\ &= B\times km\times R(\mu - \mu r)\times 2/\mu r \end{aligned}$$

Assuming B = 1200 mm, km = 10 kg/mm, μ = 0.3 and μr = 0.25, the roll balance Fw is

$$Fw > 27.6 \text{ tons}$$

Fig. 5 shows a relationship between the friction coefficient μr between rolls and the necessary balance force Fw in the assumption that R = 230, B = 1200 mm, km = 10 kg/mm and μ = 0.3. Accordingly, a biting failure can be prevented by increasing a roll balance force or a bending force upon biting in such a range as not to exert adverse effect on the strength of a roll neck and returning the balance force to the original one or returning the roll bending force to a value suitable for a plate crown after biting.

In this way, the biting failure in a rolling mill including small diameter work rolls can be prevented by controlling the floating height of a plate and also controlling the roll bending force or roll balance force.

Fig. 6 shows the (i-1)-th stand and the i-th stand of a related art type four-stage finishing rolling mill plant. A plate 1 to be rolled passes through the (i-1)-th stand and just reaches the i-th stand. Each stand includes a housing 2_{i-1} (2_i); work rolls 3_{i-1} (3_i); back-up rolls 5_{i-1} (5_i); work roll chocks 6_{i-1} (6_i); project blocks 9_{i-1} (9_i); roll balances or roll bending devices 10_{i-1} (10_i); a reduction jack 11_{i-1} (11_i); a reduction load meter (load cell) 13_{i-1} (13_i); an inlet side plate passing guide 14_{i-1} (14_i); and an outlet side plate passing guides 15_{i-1} (15_i).

In general, a roll is desirable to be smaller in diameter for effectively deforming a plate to be rolled at a smaller rolling load and for enabling rolling at a small energy. In this regard, a work roll is desirable to be as small as possible in diameter. A practical roll, however, has a large diameter. The reason for this is due to a biting condition. For example, assuming that a friction coefficient between a plate and a roll is 0.25, mill rigidity is 550 tons/mm, reduction is 20 mm, and rolling load is 2500 tons, the diameter of the roll becomes 760 mm from the equation (1). In general, the diameter of the work roll is selected at about 800 mm. If small diameter rolls each having a diameter of about 460 mm are used for rolling, a plate to be rolled must be pressed between the rolls upon biting of the plate.

A rolling mill including hold-down rollers for pressing a plate to be rolled between rolls upon biting of the plate is shown in Fig. 1.

Fig. 1 shows a six-stage rolling mill plant including six rolling mills each having small diameter work rolls to which the present invention is applied. The rolling mill includes work rolls 3_{i-1} (3_i); intermediate rolls 4_{i-1} (4_i); back-up rolls 5_{i-1} (5_i); roll balances 10_{i-1} (10_i) for supporting the dead weights of the work rolls 3_{i-1} (3_i); an inlet side plate passing guide 14_{i-1} (14_i); an outlet side plate passing guides 15_{i-1} (15_i); hold-down rollers 17_{i-1} (17_i), 18_{i-1} (18_i) capable of being ascended/descended by hydraulic cylinders; a detector 19_i; a controller (not shown) for controlling the ascending/descending of the hold-down rollers and roll balance forces of the roll balances 10_{i-1} (10_i) in responce to a signal from the detector 19_i; and an input device (not shown) for setting an initial set. In addition, the hold-down rollers 17_{i-1}, 17_i, 18_{i-1}, 18_i can be rotated by drive units through joints (not shown); however, even in the case where such drive units are not provided, the biting of a plate to be rolled according to the present invention can be sufficiently carried out. Here, the inlet side plate passing guide 14_{i-1} (14_i) is previously provided with a level difference H_{i-1} (H_i) of 50 mm or more between a roll bite and a table, and it has such a slope as to near the roll bite level as nearing the roll bite.

While not particularly shown in the figure, the inlet plate passing guide 14_{i-1} (14_i), the outlet side plate passing guide 15_{i-1} (15_i), the hold-down rollers 17_{i-1} (17_i), 18_{i-1} (18_i) capable of being ascended/descended by hydraulic cylinders, the detector 19_i, the controller, and the input device constitutes a biting auxiliary device. Such a biting auxiliary device can be mounted on an existing rolling mill. In addition, when the roll balances 10_{i-1} (10_i) for supporting the dead weights of the work rolls 3_{i-1} (3_i) are mounted to the existing rolling mill, the roll balances can be controlled by the controller of the biting auxiliary device.

The controller and the input device may be provided separately from the rolling mill.

The operation of the hold-down roller will be first described with reference to Figs. 7 to 10.

Fig. 7 shows a state in which the plate 1 to be rolled passes through the (i-1)-th stand and moves toward the (i)-th stand. A load P0 upon biting of the rolling mill is previously set by the input device. Timings t1 and t2 are set, which allow to descend the hold-down roller 18_{i-1} of the before-stage rolling mill and the hold-down roller 17_i of the rolling mill prepared to perform the biting, respectively. The timings t1 and t2 are set in accordance with the rolling speeds of the rolling mills.

When the plate 1 is bitten between the work rolls of the (i-1)-th stand, an output signal of the load cell increases. The controller compares the output signal from the load cell with the predetermined load P0. When it is judged that the output signal exceeds the load P0 by the controller, a timer is started. When a time of the timer becomes the predetermined timing t1, the hold-down roller 18_{i-1} of the (i-1)-th stand shown in Fig. 7 is descended. Next, the time of the timer becomes the predetermined timing t2, the hold-down roller 17_i of the i-th stand shown in Fig. 8 is descended. As seen from Fig. 8, the plate 1 is restricted in gaps H_{i-1} and H_i surrounded by the hold-down rollers 17_i, 18_{i-1}, the inlet side guide 14_i, the outlet side guide 15_{i-1} and the upper surface of the table. At the moment when being bitten in the (i)-th stand, the plate 1 is buckled and deflected upward by a reaction force generated by the plate passing guide 14_i upon biting; however, as shown in Fig. 9, the floating of the plate is held-down by the hold-down rollers 18_{i-1} and 17_i. The floating height of the plate 1 is thus held-down by the hold-down rollers 17_i and 18_{i-1}, so that there can be obtained a press-in force being so large as to allow the plate 1 to be bitten between the work rolls of the i-th stand.

In this way, the plate 1 is bitten between the work rolls 3_i of the i-th stand by the sufficient press-in force, and a load detection signal of the load cell 13_i of the i-th stand increases. When the output signal from the load cell 13_i of the i-th stand becomes larger than a predetermined value, the hold-down rollers 18_{i-1} and 17_i are ascended. Such a state is shown in Fig. 10. Namely, the increase in the detection signal of the load cell 13_i means the biting of the plate 1 between the work rolls 3_i of the i-th stand, and when it is judged that the biting is sufficiently performed, the hold-down rollers 18_{i-1} and 17_i are ascended and a looper 16_i is started for performing looper control. In this embodiment, the ascending/descending of the hold-down rollers is performed on the basis of the timing of the timer; however, it is not limited thereto and may be performed on the basis of the positional detection of the plate. In any case, when being early descended, the hold-down rollers are possibly brought in contact with the plate, which causes a fear in damaging the plate. Accordingly the hold-down rollers are preferably disposed and controlled to be descended directly before the plate reaches the small diameter work rolls. In this regard, the hold-down rollers 18_{i-1} and 17_i may be simultaneously descended on the basis of the detection of the plate by the detector disposed near the small diameter work rolls. The above processing steps are shown by a flow chart in Fig. 11.

Incidentally, a torque necessary for rolling cannot be directly applied to the ends of the small diameter work rolls in consideration of the strength of a spindle, and thereby the small diameter work rolls are indirectly driven through intermediate rolls or back-up rolls each having a large thickness. Accordingly, upon biting of a plate to be rolled, that is, during the rolling load becomes a normal state, a slip is possibly generated between the work roll and the intermediate roll or back-up roll. To solve such an inconvenience, a contact load between the work roll and the intermediate roll or back-up roll is increased by increasing the output of the balance cylinder 10_{i-1} for the work roll of the (i-1)-th stand in Fig. 1 in such a range as not to exert adverse effect on the strength of the neck portion of the work roll, or maximizing the output of the work roll bending cylinder for a specified period of time after biting. Such a processing step will be described with reference Fig. 12. First, a biting load P0 for a plate to be rolled, a balance force (or roll bending force) for the work roll, and a time "ta" are set. Here, when the load signal of the load cell of the (i-1)-th stand exceeds the predetermined load P0, it is judged that the plate 1 is bitten at the (i-1)-th stand, and the balance of the work rolls of the i-th stand is maximized so as to maximize the contact force with the intermediate rolls. On the other hand, when the output signal from the load cell of the i-th stand exceeds the predetermined load P0, it is judged that the biting of the plate at the i-th stand is performed, and the timer is started. Then, when a time of the timer exceeds a predetermined value, the roll balance force (or roll bending force) is returned into a set value. As a result, the biting which is most important problem in the case using the small diameter work rolls can be solved, and thereby the small diameter work rolls can be freely used.

In addition, the hold-down roller is not particularly specified in its shape; however, it has the following feature. In the case of using the hold-down roller narrower than the width of a plate to be rolled, the hold-down roller can be reduced in size, and thereby the cylinder for ascending/descending the hold-down roller can be also reduced in size. On the other hand, in the case of using the hold-down roller wider than the width of the plate, the hold-down roller does not tend to damage the plate even when it is brought in contact with the plate. In addition, the plate can be prevented from being damaged by rotating the hold-down roller by a drive unit and driving it at least until the plate is bitten between the work rolls.

The hold-down rollers are provided on the inlet and outlet sides of a rolling mill in this embodiment; however, one hold-down roller may be provided either of the inlet and outlet sides of a rolling mill in accordance with a distance between rolling mills. Also, the same hold-down rollers are not necessarily provided on the inlet and outlet sides of a rolling mill. For example, a hold-down roller narrower than the width of a plate may be provided on the inlet side of a rolling mill and a hold-down roller wider than the width of the plate may be provided on the outlet side of the rolling mill. With this configuration, the plate can be fed to the next rolling mill without damaging the plate on the outlet side of the rolling mill. In addition, in the case where a plurality of rolling mills are arranged, hold-down rollers each being narrower than the width of a plate may be provided on the before-stage rolling mills and hold-down rollers each being wider than the width of the plate may be provided on the after-stage rolling mills.

The roll change in the rolling mill plant of the present invention will be described below. In a state in which the inlet side plate passing guides 14 and the outlet side plate passing guides 15 are left as they are, the work roll 3 cannot be changed because it is brought in contact with the roll chock 6 of the work roll 3. Accordingly, as shown in Fig. 13, the looper 16_i provided between stands is rotated to a rising end, and then the inlet side plate passing guide 14_i of the i-th stand is retracted from the i-th stand by a retracting cylinder 21_i provided at the (i-1)-th stand. Similarly, the outlet side plate passing guide 15_i is retracted by a retracting cylinder 20_i. In such a state, the work roll 3 is changed.

Although the related art type finishing rolling mill has adopted work rolls each having a thickness of 800 mm, even a multi-stage rolling mill plant including small diameter work rolls each having a diameter of 500 mm or less (for example, 360 mm) to which the present invention is applied enables a plate to be hot-rolled to be certainly bitten.

Next, another embodiment of the present invention will be described.

Fig. 14 shows a four-stage rolling mill plant to which the present invention is applied, in which a hot-rolling oil is sprayed on work rolls and back-up rolls. In a rolling mill of this four-stage rolling mill plant, a hot-rolling oil such as beef tallow oil or a synthetic ester is applied from spray nozzles 22 provided at the inlet side of the work rolls, or the hot-rolling oil is applied from spray headers 24 after roll cooling water adhering on the surface of the rolls is removed with wipers 23 provided on the inlet side of the back-up rolls. In such a related art rolling mill, there occurs a failure in biting of a plate to be rolled because a frictional force between the work roll and the plate is reduced by the presence of the hot-rolling oil. Accordingly, the supply of the rolling oil is stopped before tail-out of the plate 1 and the rolling oil adhering on the surface of the work roll is burned up, and the oil spraying is started after the plate is bitten in the next rolling. Such a method of preventing the biting failure can exhibit the effect of the hot-rolling oil only for the half of the total length of the plate. In the present invention, hold-down rollers are provided on the inlet and outlet sides of the rolling mill as shown in Fig. 14. With this configuration, the lowering of a friction coefficient between the work roll and the plate due to lubrication by the hot-rolling oil is compensated by a press-in force applied to the plate. This eliminates the necessity of starting and stopping the supply of the hot-rolling oil, that is, allows the hot-rolling oil to be continuously supplied, thus making it possible to supply the hot-rolling oil over the entire plate.

A rolling mill of a type shown in Fig. 15 has a pair of work rolls and a pair of back-up rolls, wherein the work rolls and the back-up rolls are respectively crossed with each other within the horizontal plane for controlling a plate thickness distribution in the plate thickness direction of a plate to be rolled. Fig. 16 shows a rolling mill in which a pair of work rolls are crossed with each other within the horizontal plane for controlling the plate thickness distribution in the plate thickness direction of a plate to be rolled. Such a rolling mill uses a hot-rolling oil. In the present invention, inlet and outlet side plate passing guides are respectively provided on the inlet and outlet sides of the rolling mill and also hold-down rollers capable of being ascended/descended by hydraulic cylinders are respectively provided on the inlet and outlet sides of the rolling mill. With this configuration, the lowering of a friction coefficient between the work roll and the plate due to lubrication by the hot-rolling oil can be compensated by the press-in force applied to the plate by the plate passing guides and the pressing rolls. This eliminates the necessity of supplying/stopping the hot-rolling oil, that is, allows the hot-rolling oil to be continuously supplied, thereby making it possible to supply the hot-rolling oil over the entire plate and hence to perform preferable rolling.

Fig. 17 shows a rolling mill having rolls each being formed in a guitar-like crown shape and a pair of intermediate rolls reversely moved for controlling the plate thickness distribution in the plate thickness direction of a plate to be rolled; and Fig. 18 shows a cluster mill of a type in which a pair of work rolls are supported by a plurality of back-up rolls. Each of these rolling mills shown in Figs. 17 and 18 can be improved to give a press-in force to the plate by providing the inlet and outlet side plate passing guides on the inlet and outlet sides of the rolling mill and also providing hold-down rollers capable of being ascended/descended by hydraulic cylinders on the inlet and outlet sides of the rolling mill, and thereby it can use small diameter work rolls. As a result, such a rolling mill can be reduced in size.

The provision of the hold-down rollers and control of a roll balance force or roll bending force also allows a rolling mill including small diameter work rolls or large diameter work rolls coated with a hot-rolling oil to perform rolling without stoppage of the advance of a plate to be rolled.

A plate material produced by a continuous casting machine can be thus rolled by a rolling mill including small diameter work rolls. Namely, it becomes possible to eliminate the necessity of provision a rolling mill for preventing generation of a biting failure of small diameter work rolls in the before-stage of the rolling mill including the small diameter work rolls, and hence to reduce the total size of the rolling mill plant.

In a rolling mill including a roll grinding machine, the diameter of a work roll is gradually reduced by roll grinding, and in some cases, there occurs a biting failure of a plate to be rolled by reduction in roll diameter. Even in such a rolling mill, the biting failure can be prevented by arrangement of inlet and outlet side plate passing guides, and hold-down rollers capable of being ascended/descended by hydraulic cylinders, for example, as shown in Fig. 1. Also, in the rolling mill including the roll grinding machine, since the hold-down rollers are sufficient to be controlled only in the case that the biting of the plate presents a problem due to roll grinding, it is advantageous that a detector for detecting the roll diameter is provided on the rolling mill and the ascending/descending of the hold-down rollers and control of the roll bending force are performed when the value detected by the detector is made smaller than a predetermined roll diameter.

As described above, the present invention provides a rolling mill including small diameter work rolls without any fear in causing a biting failure of a plate to be rolled. Thus, the rolling mill can be reduced in size using such small diameter work rolls for reducing a rolling load.

Even in a rolling mill including large diameter work rolls wherein a hot-rolling oil is used for reducing a loading power, biting of a plate to be rolled can be suitably performed, and oil rolling can be performed over the entire plate in the steps from the biting to the tail-out.

A further embodiment will be described below.

Fig. 19 shows a six-stage rolling mill plant including rolling mills each having small diameter work rolls. Such a rolling mill is different from that shown in Fig. 1 in configuration of eliminating hold-down rollers for preventing floating of a plate to be rolled upon biting of the plate. Namely, a biting force necessary for biting of the plate between work rolls 3_i of the rolling mill 1 is obtained by the dead weight of the plate.

To obtain the biting force by the dead weight of the plate, at least the inlet side plate passing guide 14_i (14_{i-1}) of the inlet and outlet side plate passing guides 14_i (14_{i-1}) and 15_i (15_{i-1}) is disposed lower by a specified value than the upper portion of the lower work roll 3_i as shown in Fig. 20. Specifically, assuming that the plate thickness on the inlet side is h1 and the plate thickness on the outlet side is h2, the inlet side plate passing roll is disposed so that an interval h3 between the upper portion of the lower work roll and the inlet side plate passing roll on the work roll side satisfies the following equation:

$$h3 = (h1 - h2)/2 \tag{15}$$

Thus, the plate is deflected downward in the rolling mills 2_{i-1} and 2_i. Namely, although the plate tends be floated when the plate is bitten between the work rolls of the rolling mill 2_i, the floating of the plate can be prevented by the dead weight of the plate, and thereby the plate can be smoothly bitten between the work rolls.

In addition, the interval between the upper portion of the lower work roll and the inlet side plate passing guide on the work roll side may be previously determined on the basis of the equation using the estimated maximum plate thickness on the inlet side and the minimum plate thickness on the outlet side; or the inlet side plate passing guide may be variable by calculating the equation (15) using the rolling schedule and data measured by a plate thickness meter provided on the inlet side of the rolling mill. In this way, by making variable the inlet side plate passing guide, the interval can be matched with the vertical movement of the lower work roll in accordance with the rolling schedule.

Moreover, as described, a rolling bending force or roll balance force may be used in combination upon biting.

There can be provided a rolling mill plant using small diameter work rolls without a failure in biting of a plate to be rolled by provision of an inlet side plate passing guide for making use of the dead weight of the plate. Thus, a rolling mill smaller in size than that including hold-down rollers can be provided, and thereby the entire rolling mill plant can be made compact.

In addition, a rolling mill including large diameter work rolls wherein a hot-rolling oil is used for reducing a rolling power to which the inlet side plate guide specified in arrangement based on the equation (15), eliminates a failure in biting of a plate to be rolled and enables oil rolling over the entire plate in the steps from the biting to the tail-out.

Claims

1. A hot strip mill plant for rolling a plate (1) to be hot-rolled using a plurality of rolling mills each including work rolls (3), said rolling mill including said work rolls comprising:

   plate passing guide members (14, 15) each being provided in such a manner as to be sloped and to vertically surround a pass line of said plate (1); and
   rollers (17, 18) each capable of being ascended/descended to a desired position for holding-down a floating of said plate and provided near each of said plate passing guide members.

2. A hot strip mill plant according to claim 1, wherein said roller (17, 18) is rotated by a drive unit.

3. A hot strip mill plant according to claim 1, each of the before-stage ones of a plurality of said rolling mills has said rollers each being narrower than the width of said plate, and each of the after-stage ones of a plurality of said rolling mills has said rollers each being narrower than the width of said plate.

4. A hot strip mill plant according to claim 1, at least one of a plurality of said rolling mills is a cluster mill in which said work rolls (3) are supported by a plurality of back-up rolls (5).

5. A hot strip mill plant according to claim 1, wherein at least one of a plurality of said rolling mills includes a grinding machine for grinding said work rolls (3) on line.

6. A rolling mill comprising:

   a pair of small diameter work rolls (3) for rolling a plate material (1) continuously fed;
   a pair of intermediate rolls (4);
   a pair of back-up rolls (5);
   a hydraulic system for imparting an oil pressure to said work rolls (3);
   plate passing guide members (14, 15) each being in such a manner as to vertically surround a pass line of said plate material (1) for guiding the advance of said plate material; and
   rollers (17, 18) each capable of being ascended/descended to a desirable position for holding down a floating of said plate material (1) and provided near each of said plate passing guide members (14, 15).

7. A rolling mill according to claim 6, wherein a pair of said intermediate rolls (4) are movable in the axial direction of said intermediate rolls.

8. A rolling mill according to claim 6, wherein said hydraulic system for imparting an oil pressure to said work rolls (3) controls contact forces applied between said work rolls (3) and said intermediate rolls (4) depending on the ascending/descending of said rollers (17, 18).

9. A rolling mill according to claim 6, wherein either of said work roll (3), said intermediate roll (4) and said back-up roll (5), or each of said work roll (3) and said back-up roll (5) is formed in a curved shape asymmetric with respect to a pass center and vertically point-symmetric for feeding said roll in the axial direction thereof thereby changing a gap profile between said rolls.

10. A four-stage rolling mill plant including rolling mills each having a pair of work rolls (3), a pair of back-up rolls (5), and a system (22) for scattering a hot-rolling oil to said work rolls (3), said rolling mill having said work rolls comprising:

    plate passing guide members (14, 15) each being provided in such a manner as to vertically surround a pass line of a plate material (1); and
    rollers (17, 18) each capable of being ascended/descended to a desirable position for holding down a floating of said plate and provided near each of said plate passing guide members (14, 15);
    wherein said plate material (1) is introduced between said work rolls (3) while the hot-rolling oil is scattered on said work rolls.

11. A four-stage rolling mill plant according to claim 10, wherein said work rolls (3) are paired to be crossed with each other and said back-up rolls (5) are also paired to be crossed with each other for changing a profile of a roll gap thereby changing a plate crown.

12. A biting auxiliary device in a rolling mill including a pair of small diameter work rolls (3), a pair of intermediate rolls (4), and a pair of back-up rolls (5), said biting auxiliary device comprising:

plate passing guide members (14, 15) each being disposed in such a manner as to be sloped and to vertically surround a pass line of a plate material (1);
rollers (17, 18) each capable of being ascended/descended for preventing a floating of said plate material (1) and disposed near each of said plate passing guide members (14, 15);
a detector (19) for detecting the position of said plate material (1); and
a controller for controlling said rollers (17, 18) on the basis of the position of said plate material (1) detected by said detector (19).

13. A biting auxiliary device according to claim 12, wherein said controller controls contact forces between a pair of said intermediate rolls (4) and a pair of said work rolls (3) on the basis of the position of said plate material (1) detected by said detector (19).

14. A rolling method using a mill including small diameter work rolls (3) for rolling a plate (1) to be hot-rolled, comprising the steps of:

descending hold-down rollers (17, 18) for holding down said plate (1) to a desirable position before said plate (1) reaches to said small diameter work rolls (3); and
ascending said hold-down rollers (17, 18) when the leading end of said plate (1) is bitten between said work rolls (3).

15. A rolling method using a rolling mill including small diameter work rolls (3) for rolling a plate material to be hot-rolled and a hydraulic system for imparting an oil pressure to said work rolls (3), comprising the steps of:

descending hold-down rollers (17, 18) for holding down said plate material (1) to a desirable position before said plate material reaches said small diameter work rolls (3);
increasing contact forces between said work rolls (3) and said intermediate rolls (4) by said hydraulic system when the leading end of said plate material is bitten between said work rolls (3); and
ascending said rollers (17, 18) after said plate (1) is bitten between said work rolls (3).

16. A rolling method using a rolling mill including small diameter work rolls (3) for rolling a plate material (1) to be hot-rolled and a hydraulic system for imparting an oil pressure to said work rolls (3), comprising the steps of:

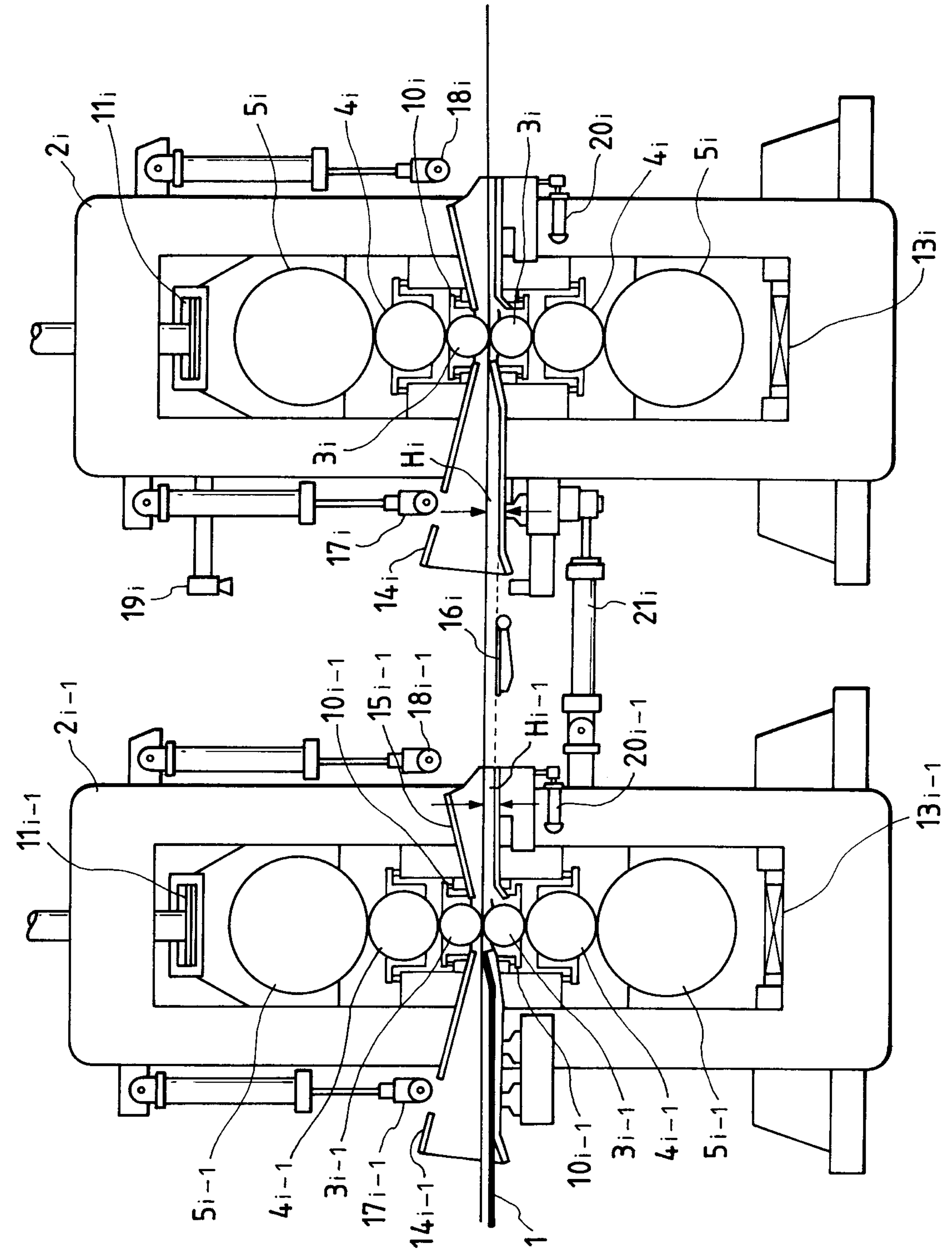
preparing hold-down rollers (17, 18) for holding-down said plate material (1) in said rolling mill;
setting said hold-down rollers (17, 18) at such positions as to restrict a pass line of said plate material (1) for preventing generation of a loop of said plate material between stands during said plate material passes directly under said hold-down rollers (17, 18) and is bitten in the next stand; and
retracting said hold-down rollers (17, 18) at such positions that said plate material (1) is not brought in contact with said rollers upon operation of a looper (16) provided between the stands after said plate material is bitten in said rolling mill.

17. A biting auxiliary device in a rolling mill including a pair of small diameter work rolls (3), a pair of intermediate rolls (4) and a pair of back-up rolls (5), comprising:

plate passing guide members (14, 15) each being disposed in such a manner as to be sloped and to vertically surround a pass line of a plate material (1);
rollers (17, 18) each capable of being ascended/descended for preventing a floating of said plate material (1) and disposed near each of said plate passing guide members (14, 15);
a detector (19) for detecting a position of said plate material (1); and
a controller for controlling said rollers (17, 18) on the basis of the position of said plate material (1) detected by said detector (19).

18. A biting auxiliary device according to claim 17, wherein said controller controls contact forces between a pair of said intermediate rolls (4) and a pair of said work rolls (3) on the basis of the position of said plate material (1) detected by said detector (19).

FIG. 1



2i
11i
5i
4i
10i
18i
3i
20i
4i
5i
13i
3i
Hi
17i
14i
19i
16i
21i
2i-1
10i-1
15i-1
18i-1
Hi-1
20i-1
13i-1
11i-1
5i-1
4i-1
3i-1
17i-1
14i-1
1
10i-1
3i-1
4i-1
5i-1

FIG. 2

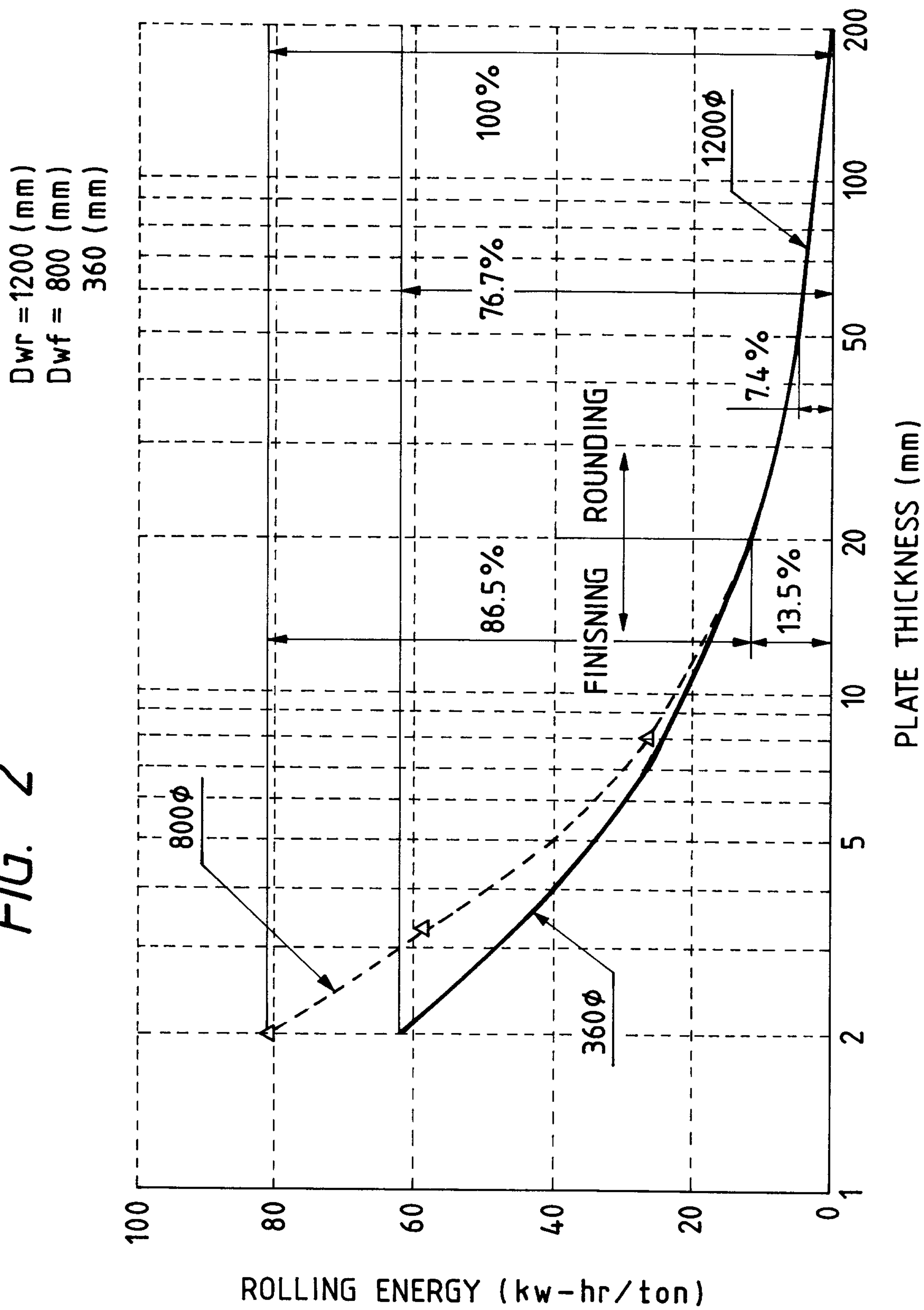

Dwr = 1200 (mm)
Dwf = 800 (mm)
360 (mm)
100%
76.7%
86.5%
7.4%
13.5%
FINISNING
ROUNDING
1200φ
800φ
360φ
ROLLING ENERGY (kw-hr/ton)
PLATE THICKNESS (mm)
0
20
40
60
80
100
1
2
5
10
20
50
100
200

FIG. 3

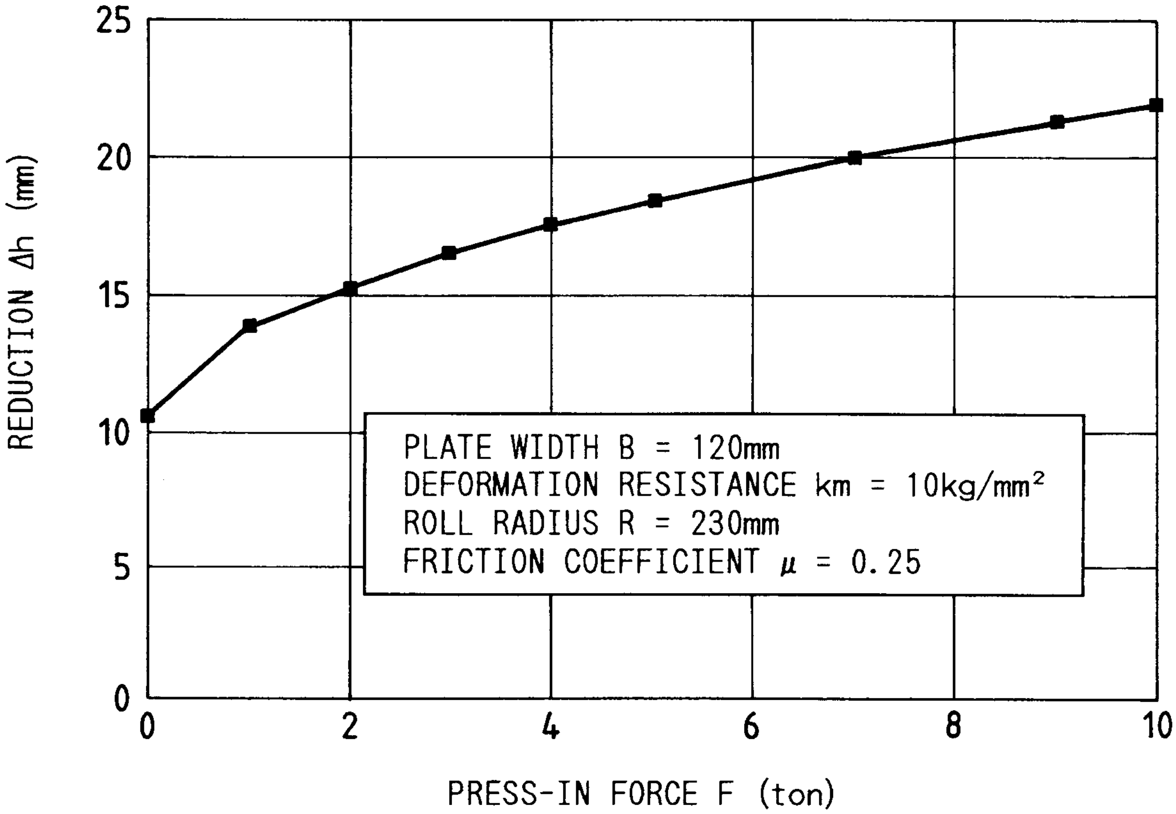

25
20
15
10
5
0
REDUCTION Δh (mm)
0
2
4
6
8
10
PRESS-IN FORCE F (ton)
PLATE WIDTH B = 120mm
DEFORMATION RESISTANCE km = 10kg/mm²
ROLL RADIUS R = 230mm
FRICTION COEFFICIENT μ = 0.25

FIG. 4

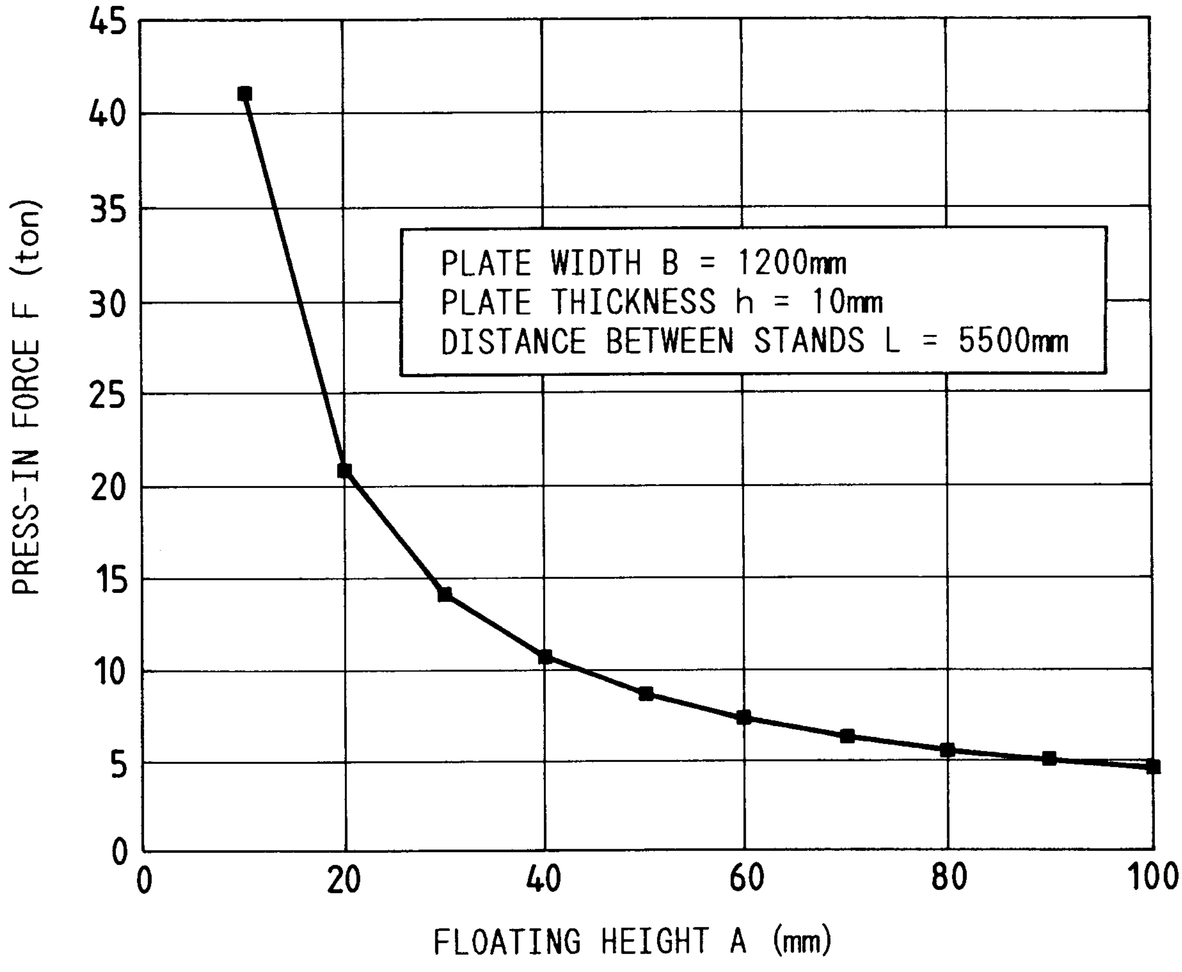

45
40
35
30
25
20
15
10
5
0
PRESS-IN FORCE F (ton)
PLATE WIDTH B = 1200mm
PLATE THICKNESS h = 10mm
DISTANCE BETWEEN STANDS L = 5500mm
0
20
40
60
80
100
FLOATING HEIGHT A (mm)

FIG. 5

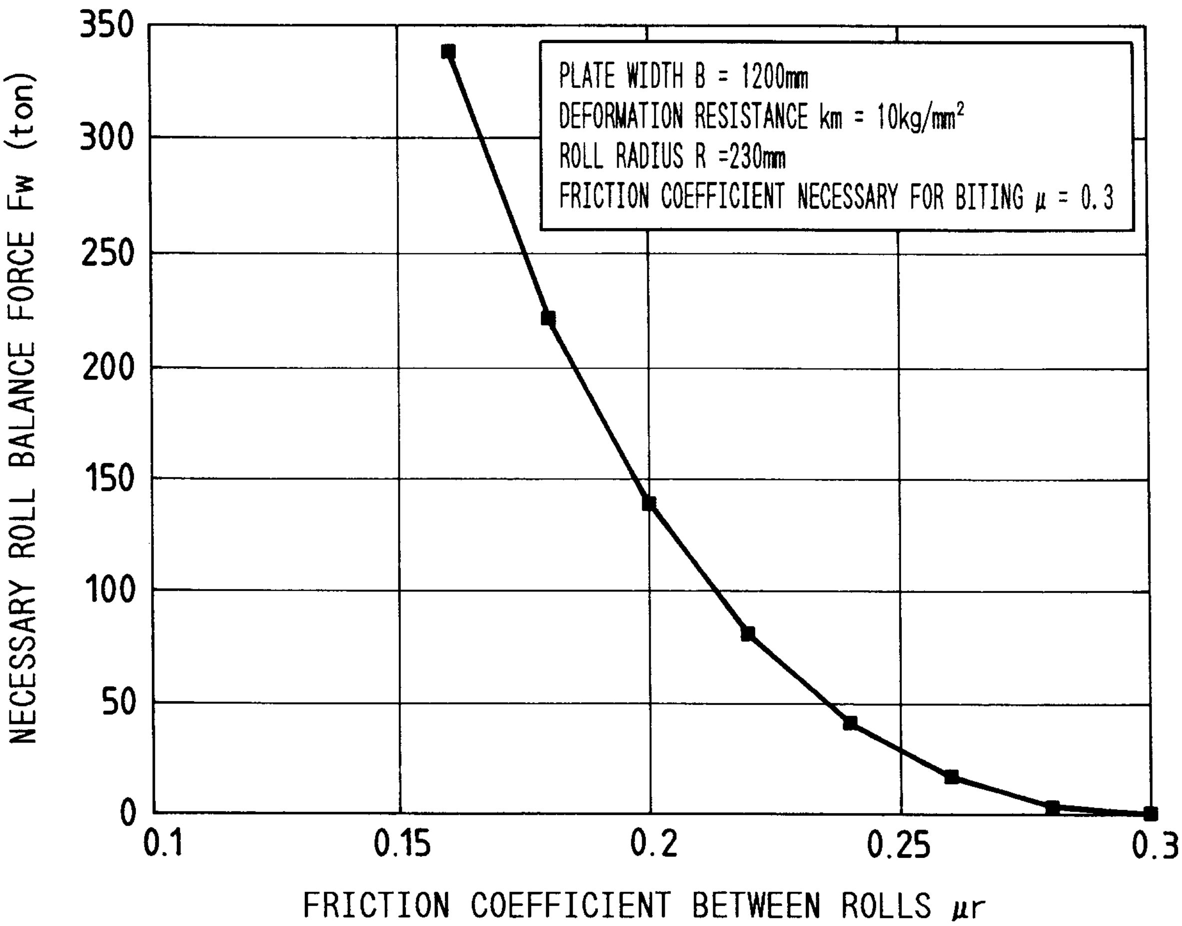


PLATE WIDTH B = 1200mm
DEFORMATION RESISTANCE km = 10kg/mm²
ROLL RADIUS R =230mm
FRICTION COEFFICIENT NECESSARY FOR BITING μ = 0.3
NECESSARY ROLL BALANCE FORCE Fw (ton)
350
300
250
200
150
100
50
0
0.1
0.15
0.2
0.25
0.3
FRICTION COEFFICIENT BETWEEN ROLLS μr

FIG. 6

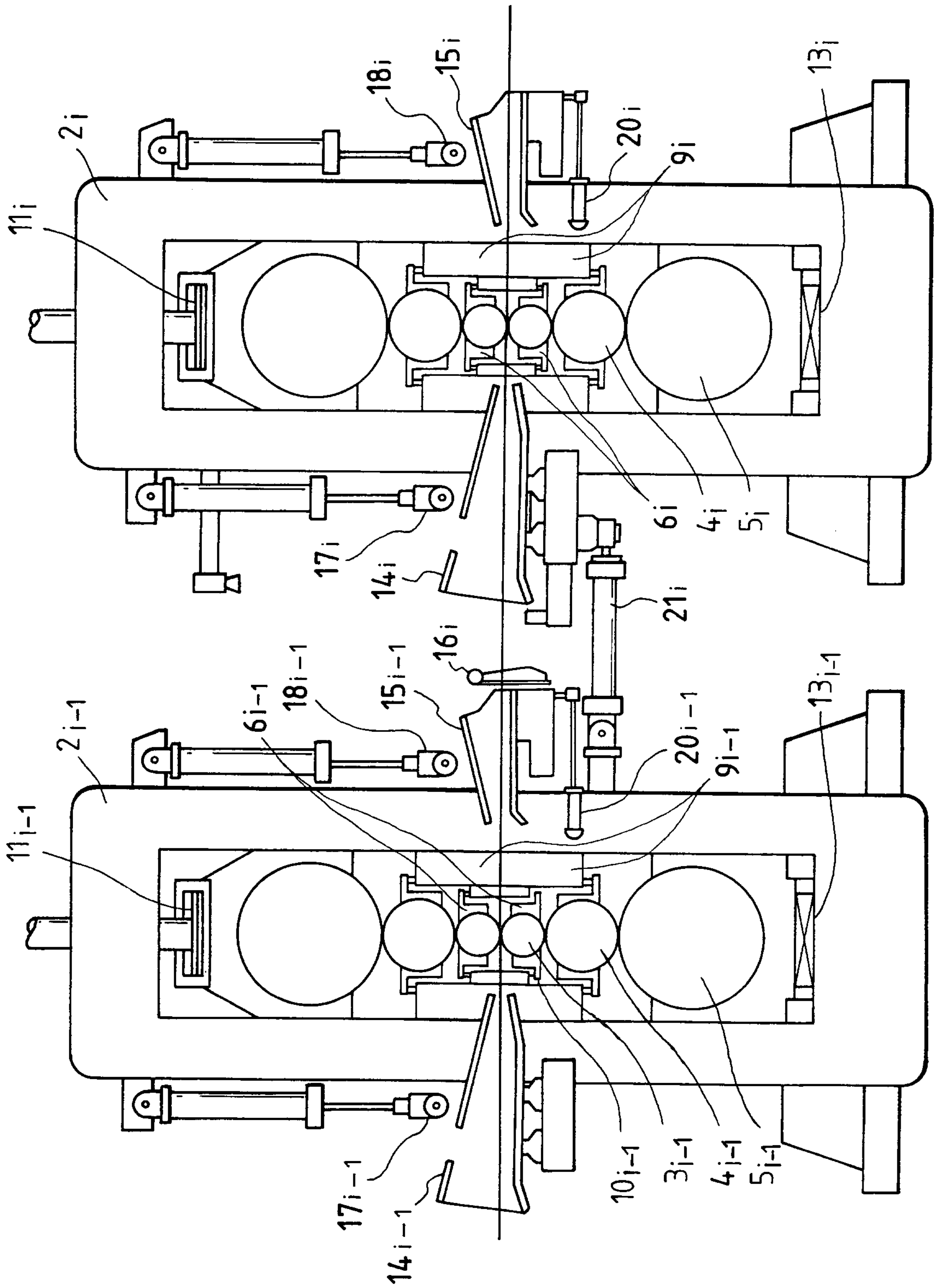

2i
11i
18i
15i
20i
9i
13i
6i
4i
5i
17i
14i
21i
16i
2i-1
11i-1
6i-1
18i-1
15i-1
20i-1
9i-1
13i-1
17i-1
14i-1
10i-1
3i-1
4i-1
5i-1

FIG. 7

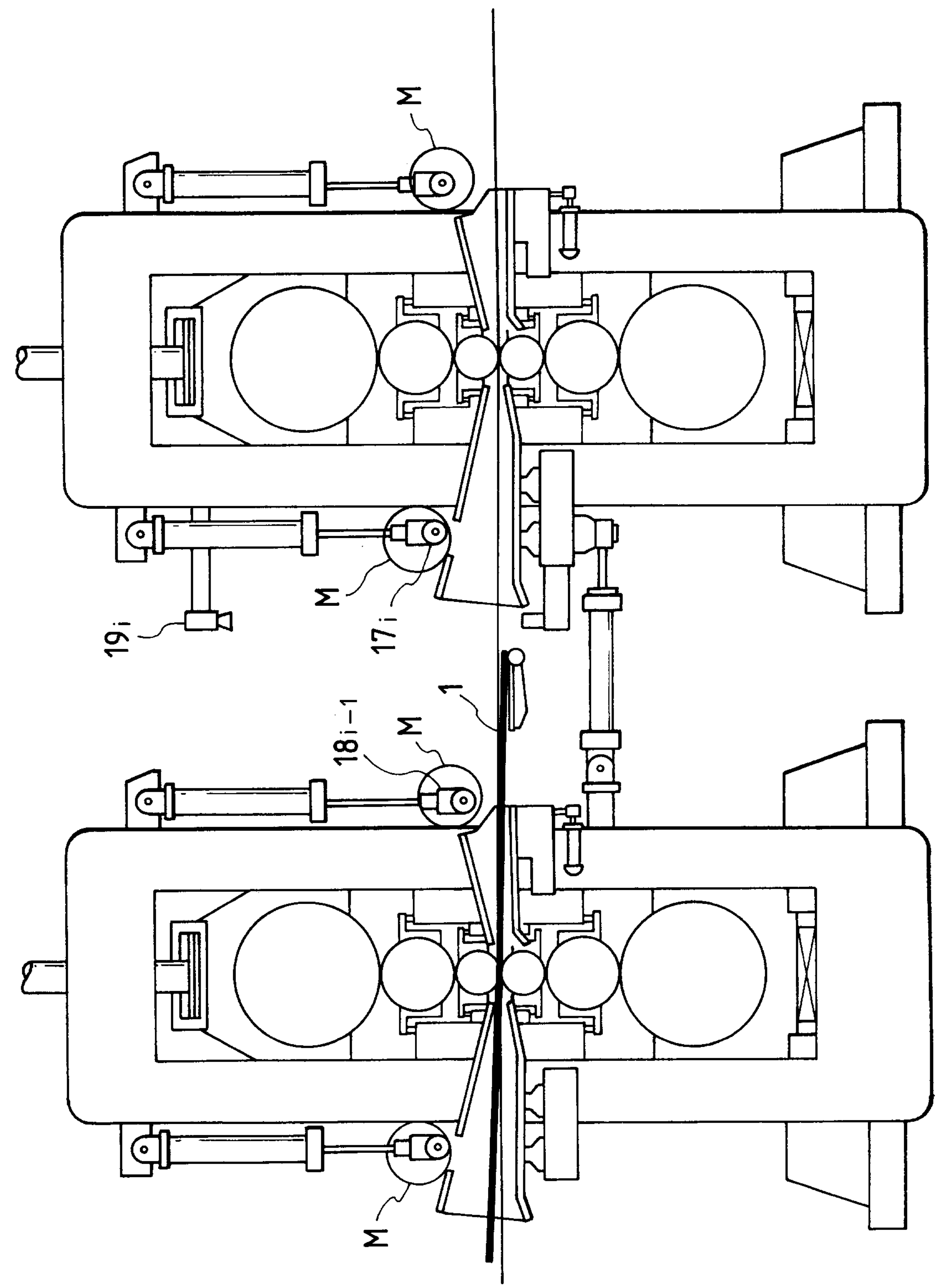


FIG. 8

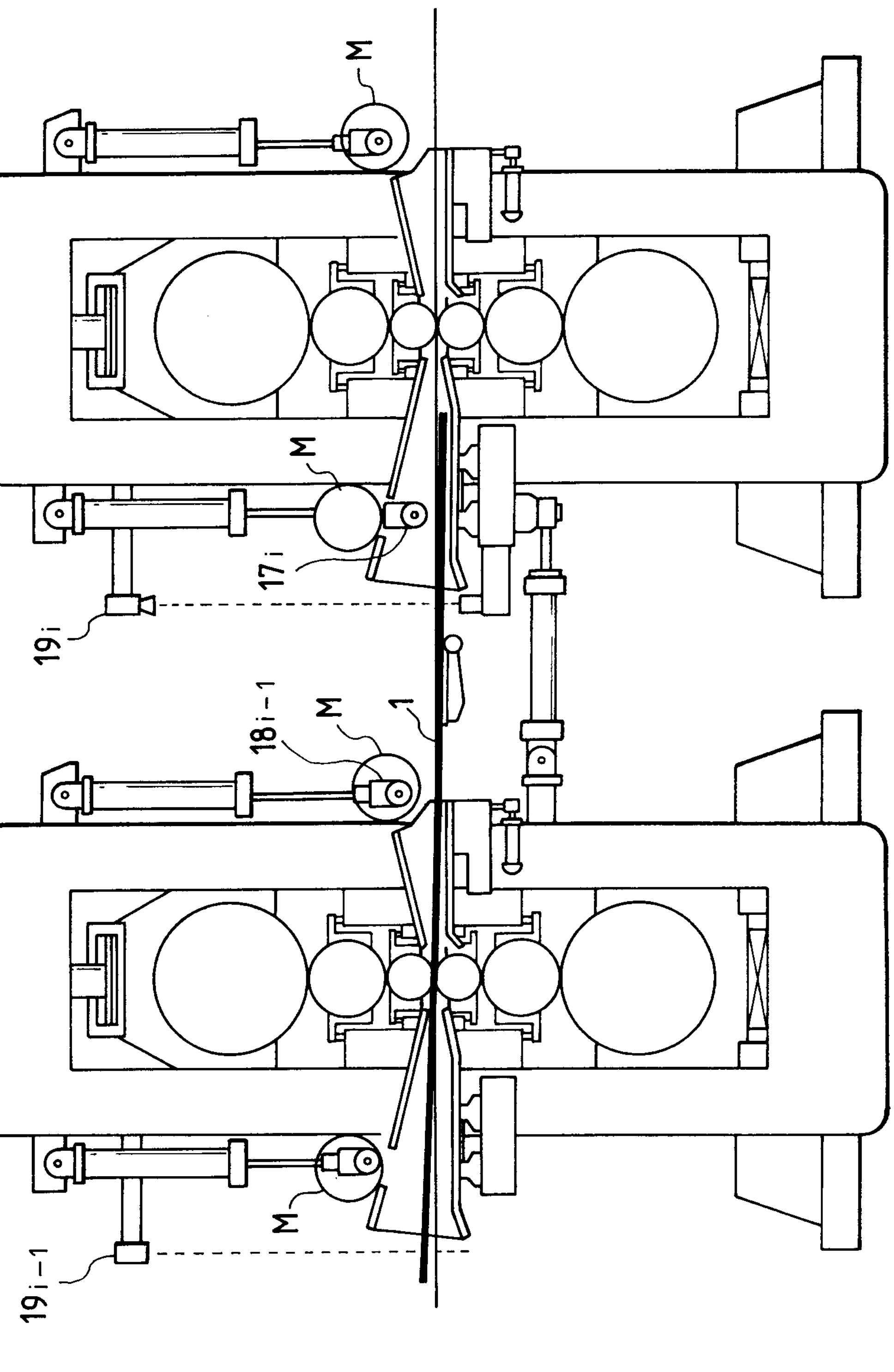


FIG. 9

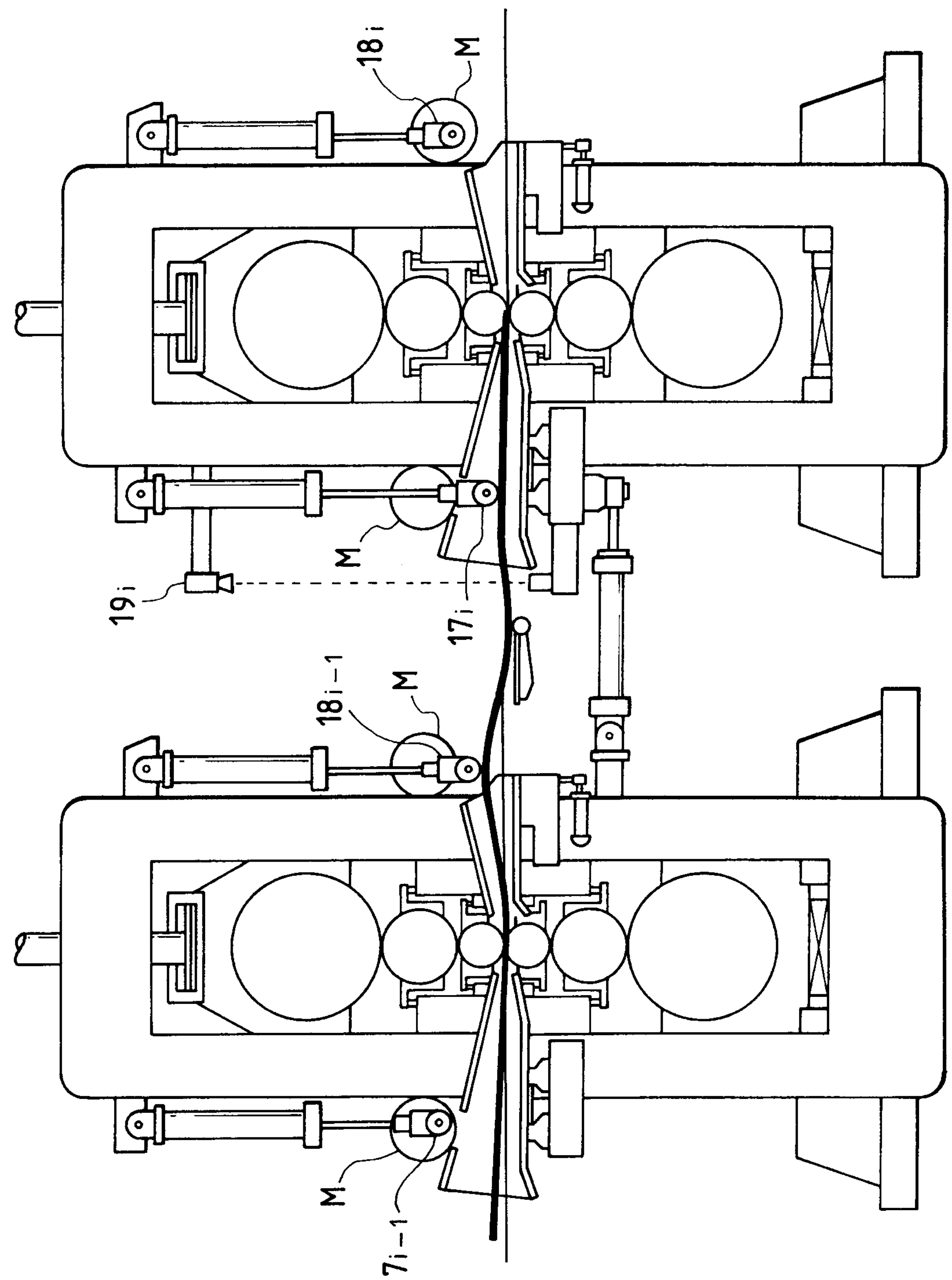


FIG. 10

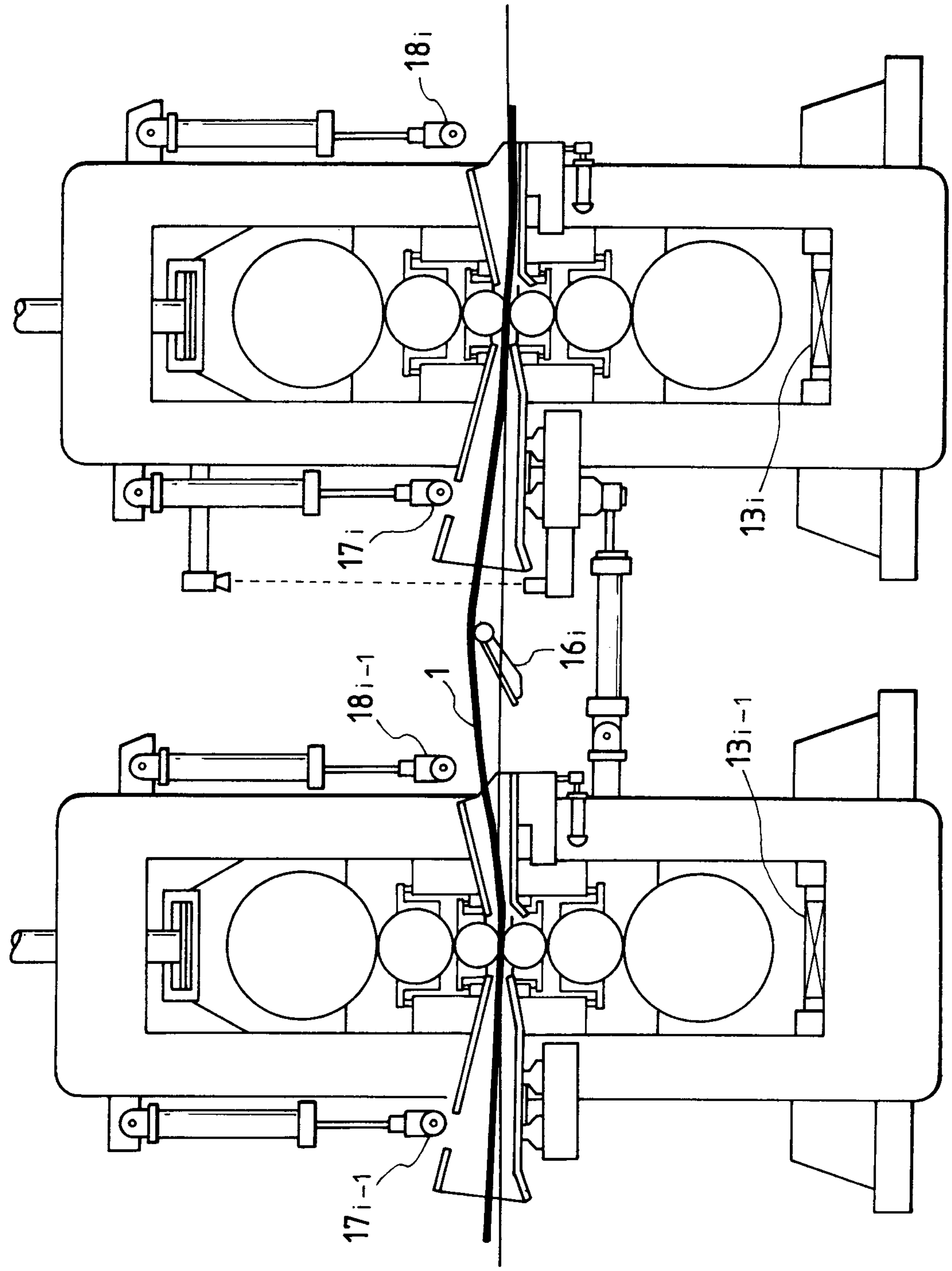


FIG. 11

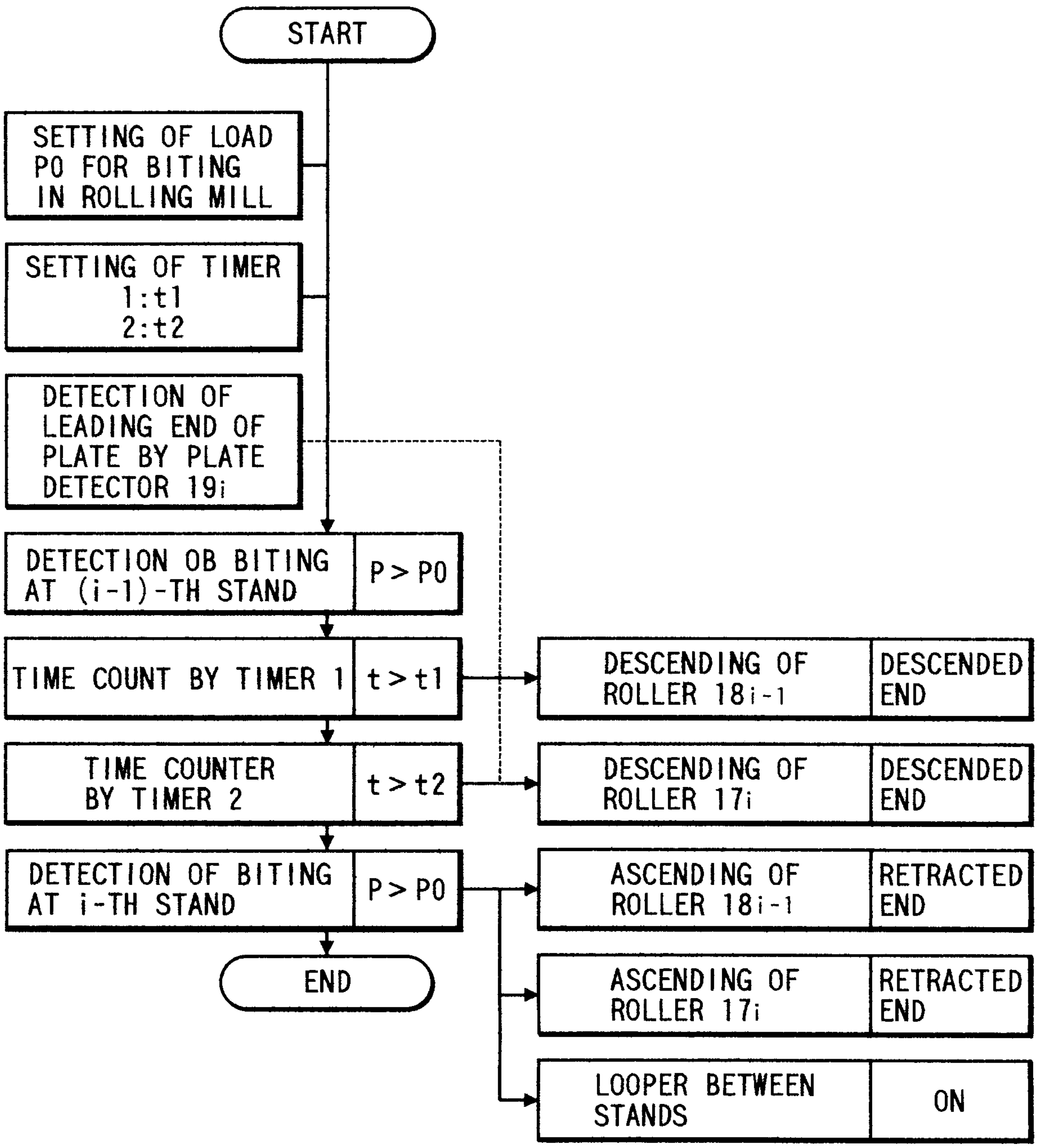

START
SETTING OF LOAD P0 FOR BITING IN ROLLING MILL
SETTING OF TIMER 1:t1 2:t2
DETECTION OF LEADING END OF PLATE BY PLATE DETECTOR 19i
DETECTION OB BITING AT (i-1)-TH STAND
P>P0
TIME COUNT BY TIMER 1
t>t1
TIME COUNTER BY TIMER 2
t>t2
DETECTION OF BITING AT i-TH STAND
P>P0
END
DESCENDING OF ROLLER 18i-1
DESCENDED END
DESCENDING OF ROLLER 17i
DESCENDED END
ASCENDING OF ROLLER 18i-1
RETRACTED END
ASCENDING OF ROLLER 17i
RETRACTED END
LOOPER BETWEEN STANDS
ON

FIG. 12

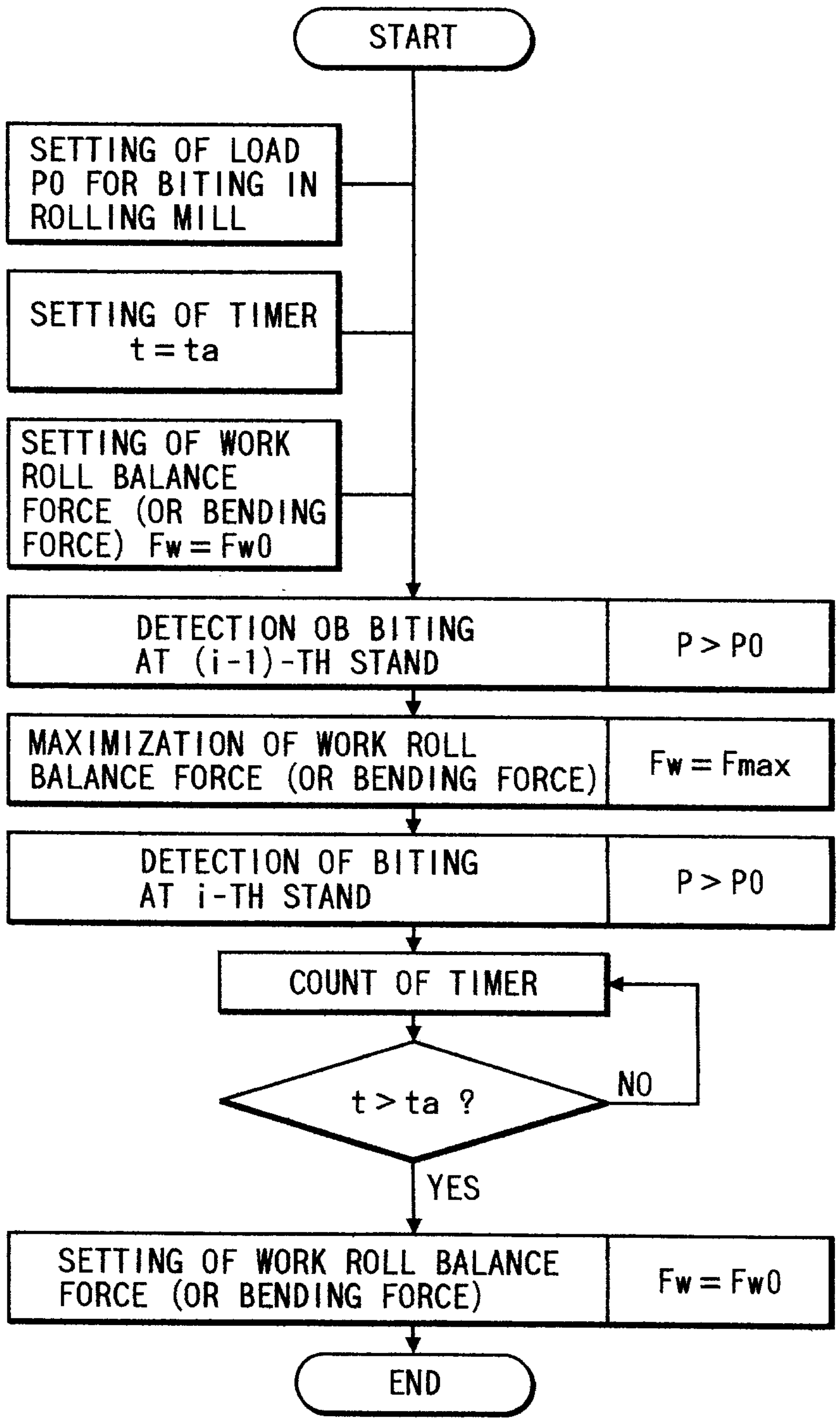

START
SETTING OF LOAD P0 FOR BITING IN ROLLING MILL
SETTING OF TIMER t = ta
SETTING OF WORK ROLL BALANCE FORCE (OR BENDING FORCE) Fw = Fw0
DETECTION OB BITING AT (i-1)-TH STAND
P > P0
MAXIMIZATION OF WORK ROLL BALANCE FORCE (OR BENDING FORCE)
Fw = Fmax
DETECTION OF BITING AT i-TH STAND
P > P0
COUNT OF TIMER
t > ta ?
NO
YES
SETTING OF WORK ROLL BALANCE FORCE (OR BENDING FORCE)
Fw = Fw0
END

FIG. 13

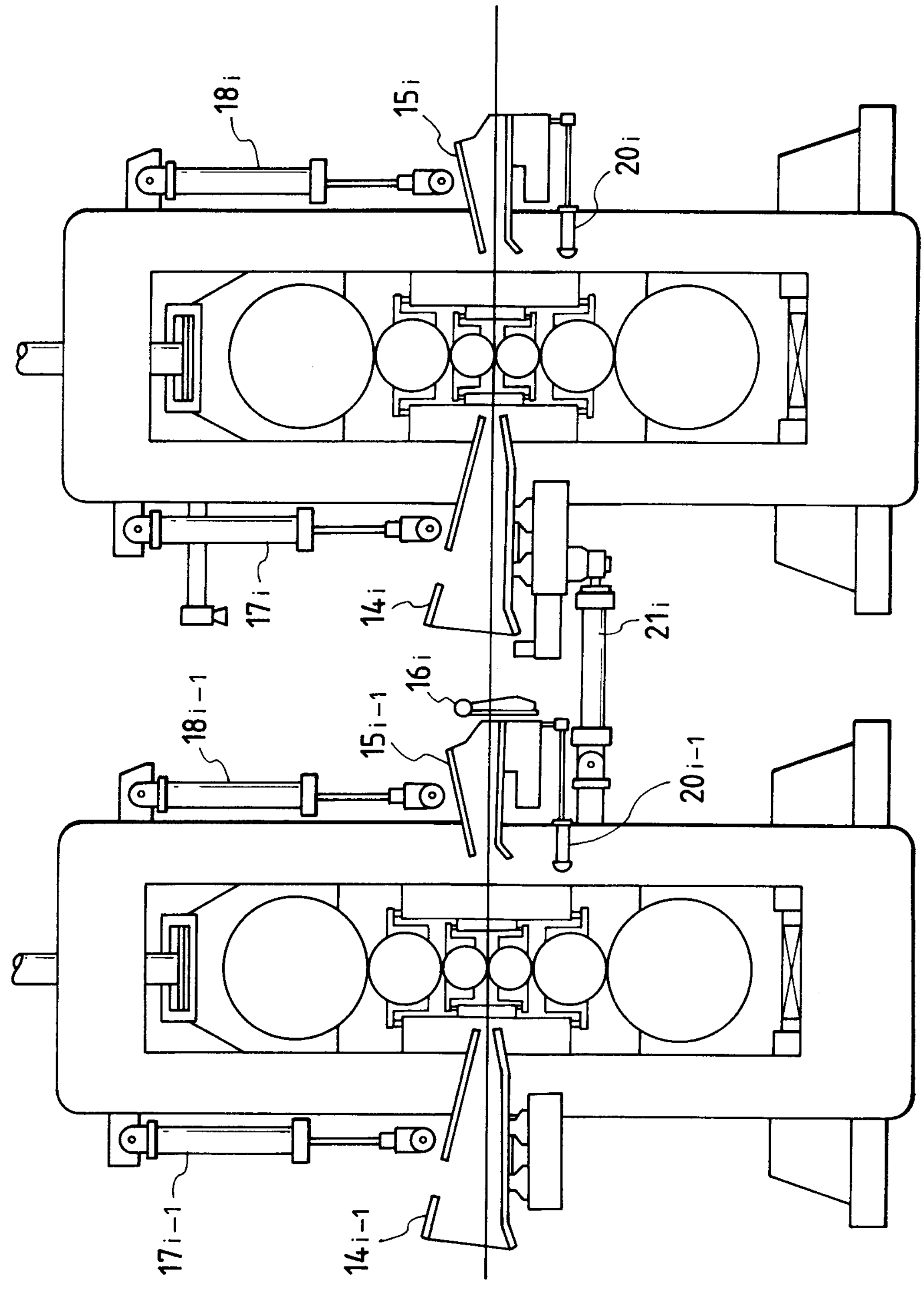


FIG. 14

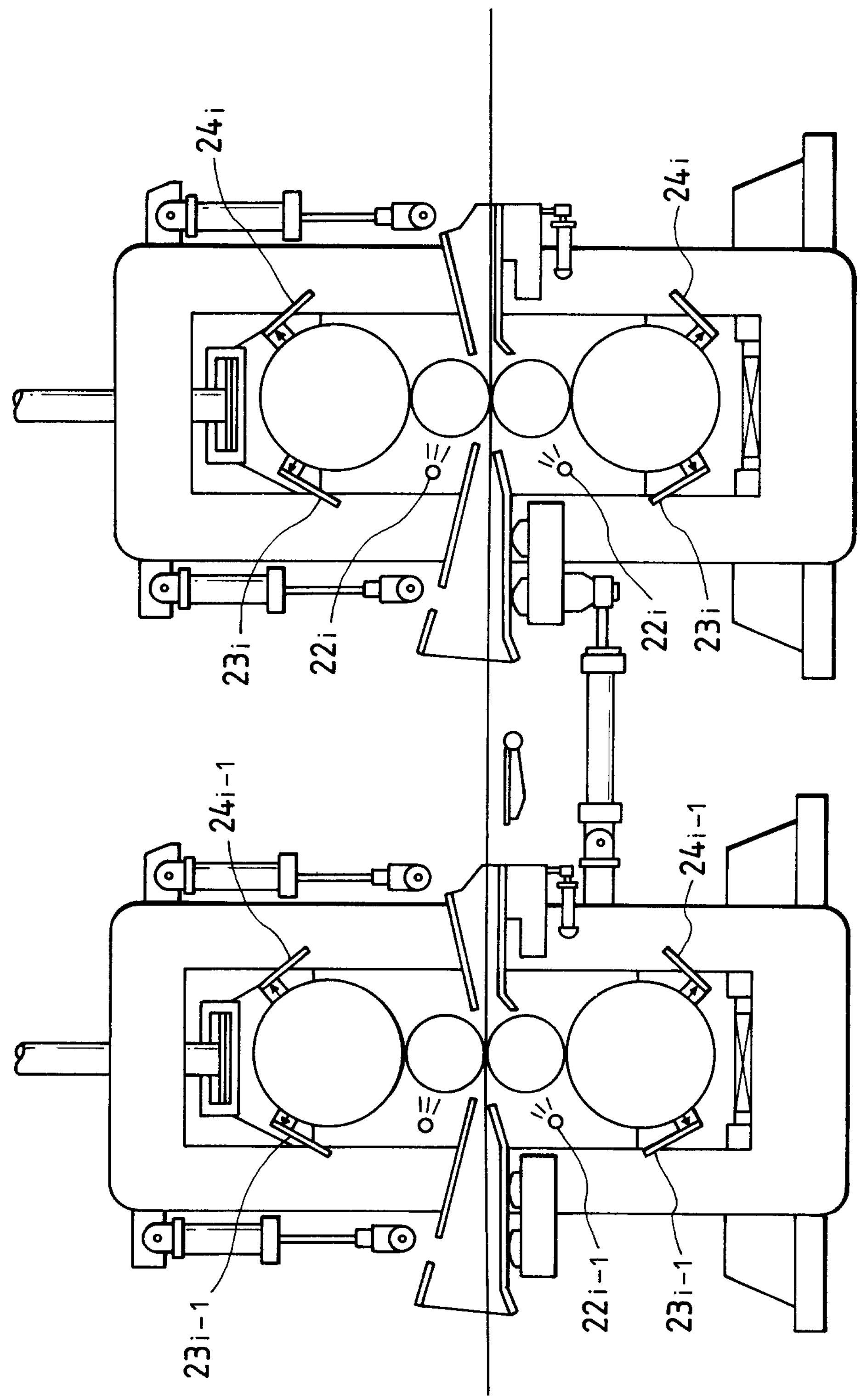


FIG. 15

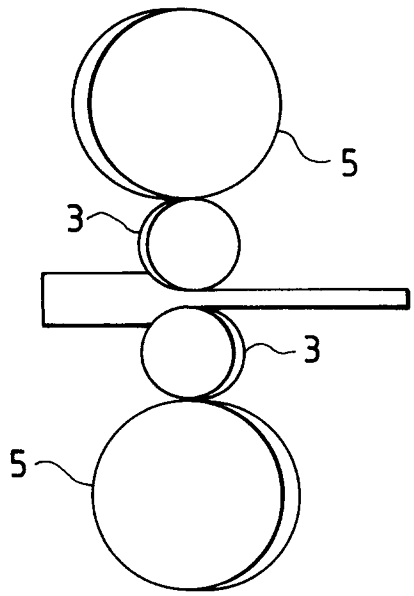


FIG. 16

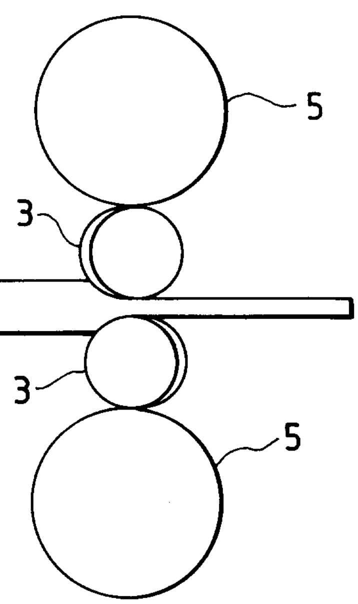


FIG. 17

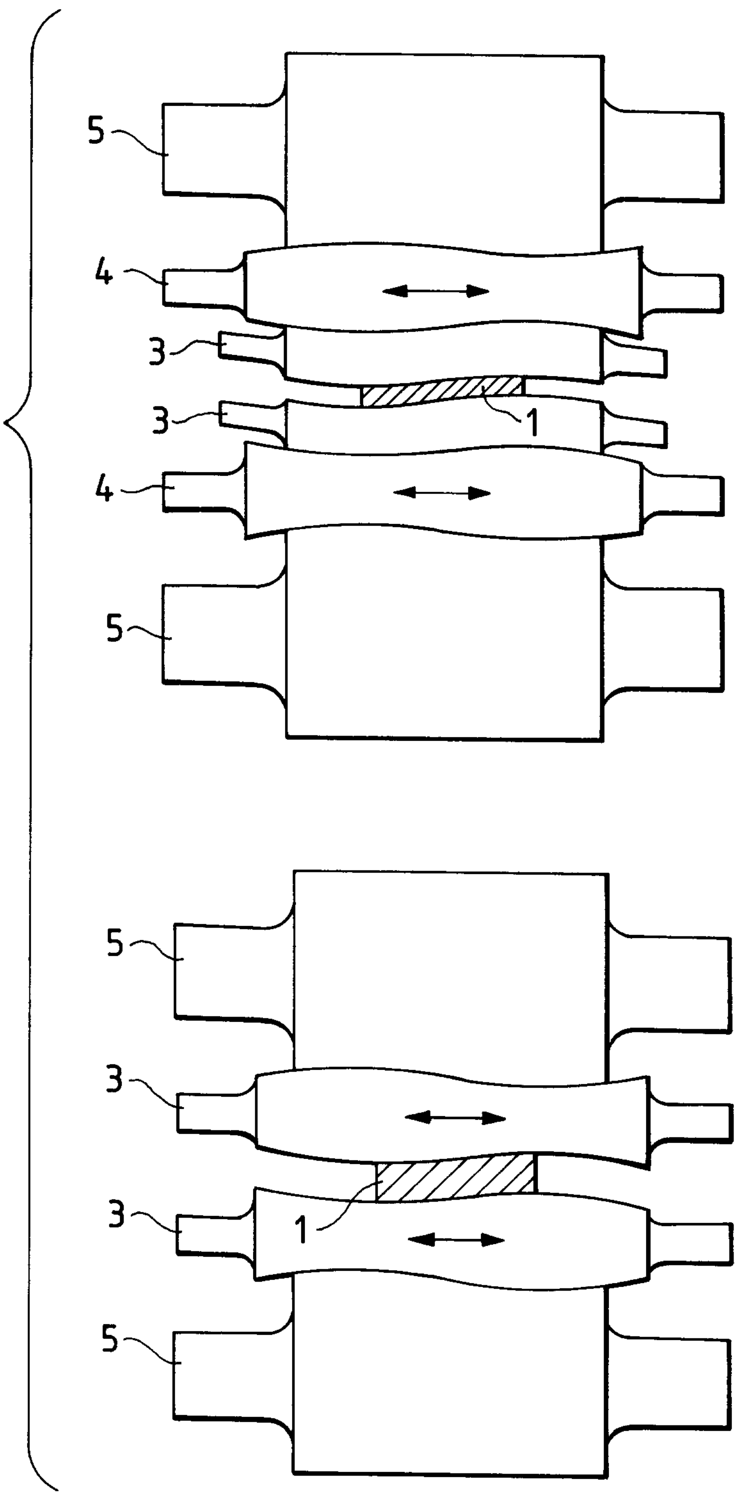


FIG. 18

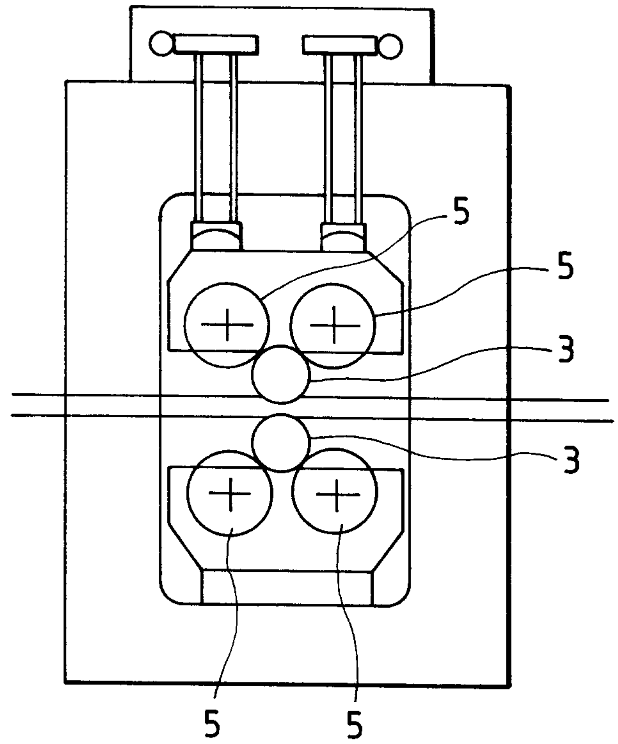


FIG. 20

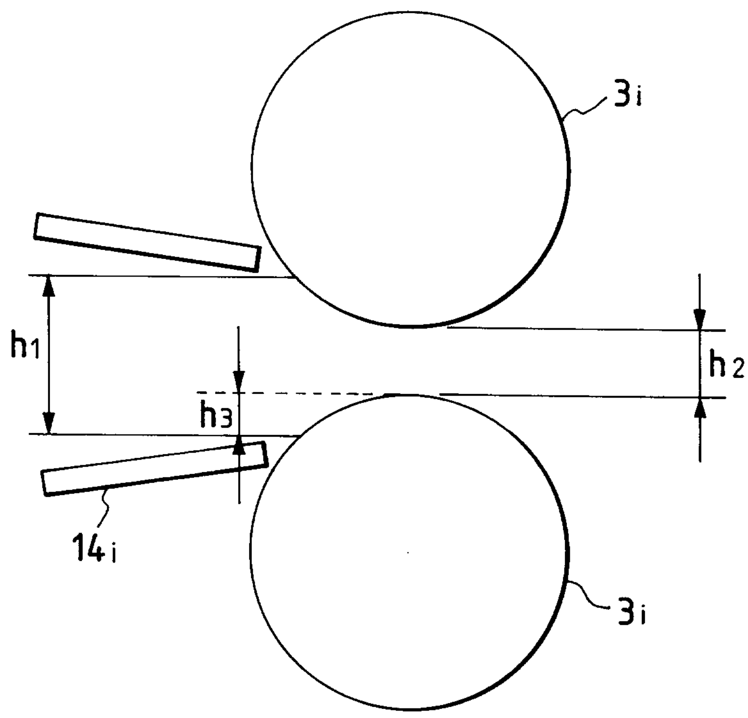
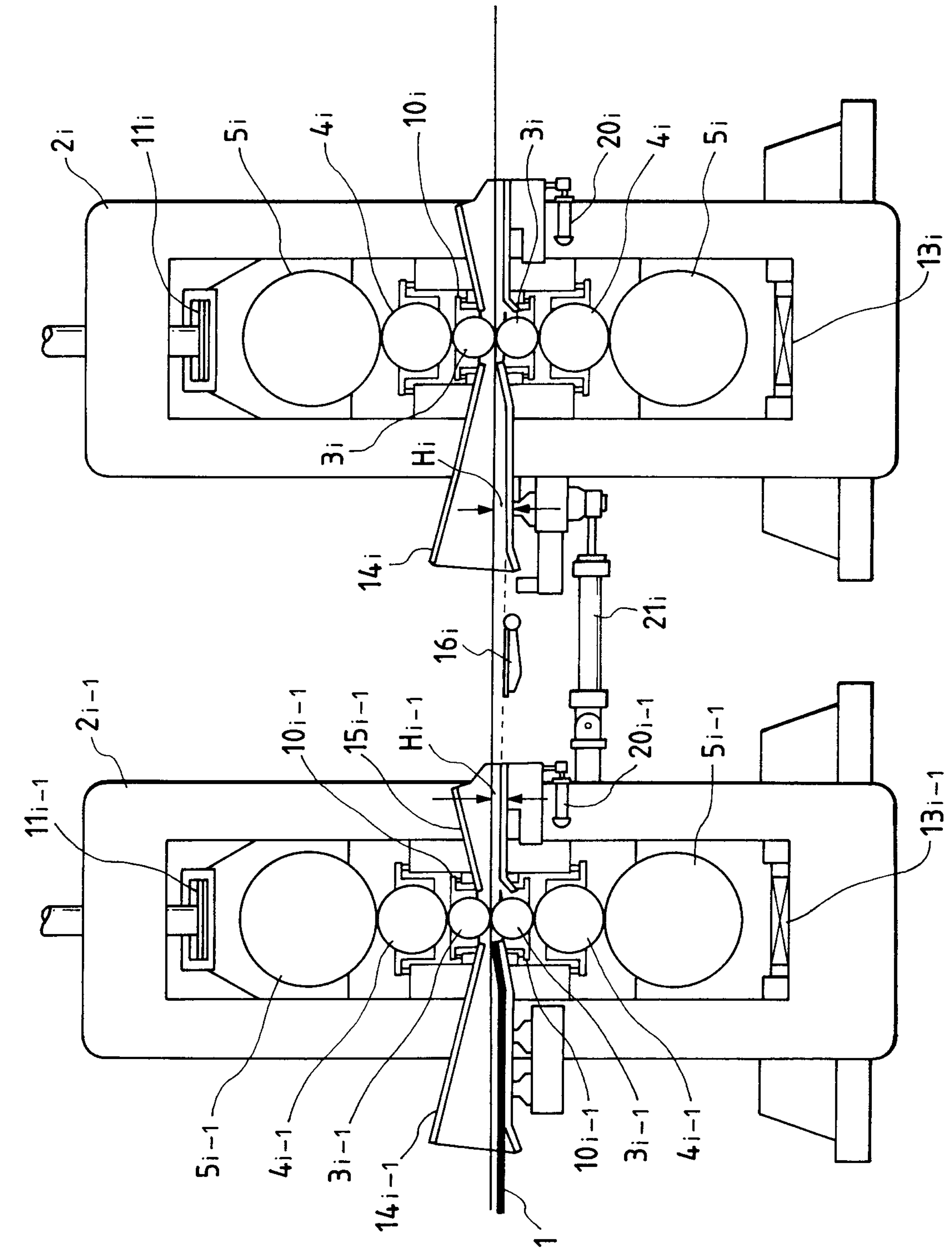


FIG. 19



2i
11i
5i
4i
10i
3i
20i
4i
5i
13i
3i
Hi
14i
21i
16i
2i-1
11i-1
10i-1
15i-1
Hi-1
20i-1
5i-1
13i-1
5i-1
4i-1
3i-1
14i-1
1
10i-1
3i-1
4i-1

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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)
Y A	PATENT ABSTRACTS OF JAPAN vol. 11, no. 241 (M-614), 7 August 1987 & JP-A-62 054516 (HITACHI), 10 March 1987, * abstract *	1,14 6,10,12, 15-18	B21B39/16
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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	11 September 1996	Plastiras, D

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A	PATENT ABSTRACTS OF JAPAN vol. 12, no. 282 (M-726), 3 August 1988 & JP-A-63 060009 (MITSUBISHI), 16 March 1988, * abstract * ---	5	
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