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(71) Applicant: **Nippon Steel & Sumitomo Metal Corporation**
Tokyo 100-8071 (JP)

(72) Inventors:
- **OGAWA, Shigeru**
  Tokyo 100-8071 (JP)
- **HIGO, Tsuyoshi**
  Tokyo 100-8071 (JP)
- **HISATSUNE, Takashi**
  Tokyo 100-8071 (JP)

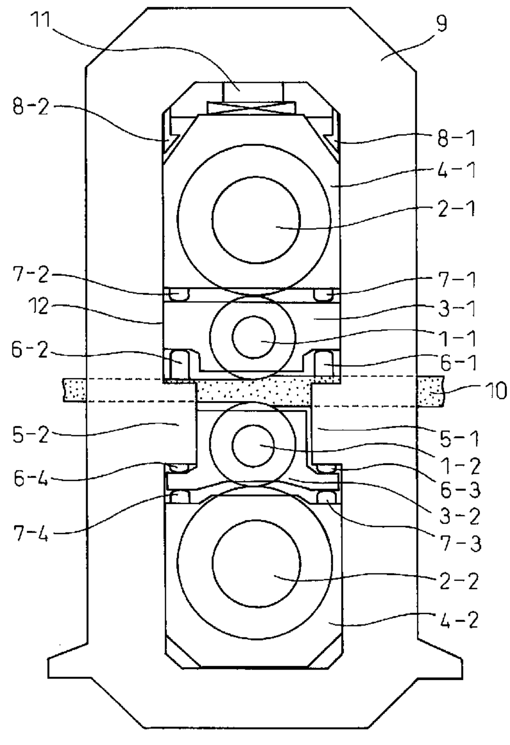
(74) Representative: **Vossius & Partner**
Siebertstrasse 4
81675 München (DE)

(54) METAL PLATE ROLLING MACHINE AND ROLLING METHOD

(57) The present invention has as its task to provide a rolling mill which can obtain a large gap between upper and lower work rolls and can impart a high response and powerful roll bending force.

To achieve this task, the rolling mill which the present invention provides is a rolling mill of a metal flat-rolled product which has a pair of upper and lower work rolls and a pair of upper and lower backup rolls which support the same, which rolling mill of a metal flat-rolled product is characterized in that hydraulic cylinders which apply increase bending force to the upper and lower work rolls are arranged at project blocks which project to the inside of a rolling mill housing, rolling direction force which is applied to a lower work roll barrel is supported by contact surfaces of a project block and the lower work roll chock, and rolling direction force which is applied to an upper work roll barrel is supported by contact surfaces of a rolling mill housing window which is positioned above the project blocks and the upper work roll chock.

Fig.1



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Description

Technical Field

[0001] The present invention relates to a rolling mill of a metal flat-rolled product which has a high response and can impart a powerful roll bending force. In particular, it relates to a rolling mill which is suitable for a plate rolling mill or **rough** rolling mill for sheet hot rolling, can obtain the maximum gap between the upper and lower work rolls, and can impart a powerful roll bending force.
Furthermore, the present invention relates to a rolling method, which uses the above rolling mill, which has a high response and can provide a powerful crown/shape control function.

Background Art

[0002] In rolling work for a metal flat-rolled product, the crown and the shape of the rolled plate become important indicators of quality. Numerous art relating to crown/shape control have been disclosed. However, for example, in rolling mills which produce thick products by multiple pass reverse rolling, such as plate rolling mills or **rough** rolling mills for sheet hot rolling, the gap between the upper and lower work rolls (roll gap) has to be made larger than the thickness of the rolling material. For this reason, restrictions are imposed on the crown/shape control devices in the design of rolling mill facilities.

[0003] For example, PLT 1 discloses a rolling method in plate rolling which rolls plate to a predetermined thickness by several passes wherein the method uses shape control devices constituted by work roll bending devices and uses the values of rolling results in a previous pass as the basis to control the roll bending force.
The type of the rolling mill which is disclosed in PLT 1 is a four-high rolling mill. This rolling mill type is the structure which is shown in FIG. 14. The rolling mill of FIG. 14 to which decrease bending devices are arranged becomes the rolling mill which is shown in FIG. 10. The two rolling mills are basically the same in structure. That is, this is a type in which an upper work roll chock 3-1 is held by arm parts which are connected to an upper backup roll chock 4-1. The arm parts have increase bending devices 6-1 and 6-2 of the upper work roll 1-1 built into them. By employing such a type, a large roll gap can be obtained.

[0004] In the rolling mills of FIG. 10 and FIG. 14, the increase bending devices 6-3 and 6-4 of the lower work roll 1-2 are built into project blocks which connect to the rolling mill housing 9. As other types of rolling mills which can give a large roll gap, as shown in FIG. 11, there are rolling mills in which at both the upper and lower backup roll chocks 4-1 and 4-2 hold the work roll chocks 3-1 and 3-2.

[0005] Note that, an "increase bending device" means a hydraulic device which imparts a force to a work roll chock in a direction enlarging the roll gap. An "increase bending device" is the general term for a device including an actuator comprised of a hydraulic cylinder. However, in the present invention, for simplification of the explanation, an "increase bending device", unless otherwise stated, will indicate that actuator comprised of a hydraulic cylinder. The force which is applied by the increase bending device to the work roll will be called the "increase bending force".
On the other hand, a hydraulic device which gives a force to a work roll chock in a direction reducing the roll gap will be called a "decrease bending device" and the force which is applied to the work roll due to this will be referred to as the "decrease bending force". Further, a "decrease bending device" is the general name for a device including the actuator comprised of a hydraulic cylinder. However, in the present invention, for simplification of the explanation, a "decrease bending device", unless otherwise stated, will indicate that actuator comprised of a hydraulic cylinder.

[0006] PLT 2, as shown in FIG. 12, discloses a rolling, mill in which the increase bending devices 6-1 and 6-2 of the work rolls are built into the work roll chocks 3-1 and 3-2.

[0007] PLT 3 discloses a roll cross type of rolling mill. This rolling mill also, as shown in FIG. 12, has the increase bending devices 6-1 and 6-2 built into the work roll chocks 3-1 and 3-2.

[0008] PLT 4, as shown in FIG. 13, discloses a rolling mill which has a work roll shift function. This rolling mill has increase bending devices 6-1 and 6-2 built into project blocks 5-1 and 5-2 which are formed integrally with the rolling mill housing. Note that, in the rolling mill which is disclosed in PLT 4, a plurality of hydraulic cylinders of the increase bending devices are arranged in the roll axial direction so that no biased load is applied at the time of shifting the work rolls. Note that, in general, rolling mills of plate do not have decrease bending devices as shown in FIG. 14. (See PLT's 1, 2, 3, and 4.)
However, a rolling mill according to the present invention is predicated on having decrease bending devices for imparting a powerful crown/shape control function. For this reason, FIG. 10, FIG. 11, FIG. 12, and FIG. 13 show the case where there are decrease bending devices.

Citations List

Patent Literature

[0009] PLT 1: Japanese Patent Publication No. 6-87011 A1

PLT 2: Japanese Patent Publication No. 62-220205 A1
PLT 3: Japanese Patent Publication No. 6-198307 A1
PLT 4: Japanese Patent Publication No. 4-52014 A1

Summary of Invention

Technical Problem

[0010] The typical plate rolling mill such as disclosed in PLT 1 (rolling mill which is shown in FIG. 10 and FIG. 11) is designed having the ability to obtain a large roll gap as its highest priority. That is, arm parts which are connected to the upper backup roll chock 4-1 which is set and controlled in upper and lower positions by a reduction device 11 holds the upper work roll chock 3-1 in structure. Further, the arm parts, which are structurally restricted in size, have the increase bending devices 6-1 and 6-2 built into them, so building in large capacity hydraulic cylinders is difficult. For this reason, a powerful roll bending force cannot be imparted.

[0011] For example, in final rolling mills of hot strip mills which have work roll diameters of 800 mm or so as well, work roll bending devices of capacities exceeding 200 tf/chock are being used in practice. As opposed to this, even in plate rolling mills which have work roll diameters of 1000 mm or so, only 200 tf/chock or so work roll bending devices are being used in practice. From the comparison of roll diameters, it is clear that larger capacity roll bending forces are required.

[0012] Here, the roll deflection, which is an indicator of the effect of roll bending, is inversely proportional to the cross-sectional secondary moment of the roll if the bending moment which is applied is the same. Therefore, the rolling bending effect of a work roll diameter of 1000 mm becomes as much as 60% inferior compared with a final rolling mill of a hot strip mill with a work roll diameter of 800 mm.

[0013] For this reason, as the crown/shape control devices of plate rolling mills, roll cross function devices or roll shift function devices are being commercialized and mainly used. Work roll bending devices are not used that much.

However, for roll cross functions or roll shift functions, it is difficult to quickly change the settings during rolling. Therefore, disturbance factors during rolling cannot be eliminated, so the shape control must be said to be incomplete.

[0014] On the other hand, like in the rolling mills which are disclosed in PLT's 2 and 3 (FIG. 12), when the increase bending devices 6-1 and 6-2 are built into the work roll chocks 3-1 and 3-2, the strokes of the hydraulic cylinders can be made longer. Due to this, a large roll gap can be realized. Further, large capacity hydraulic cylinders can also be built in, so even with plate rolling mills, a practical work roll bending effect can be expected. On the other hand, the work rolls 1-1 and 1-2 are easily worn down by the backup rolls due to the rolling operation, so have to be periodically replaced. For this reason, with each changing operation, the hydraulic piping of the increase bending devices has to be detached and reattached. Due to this, not only does the roll changing time become longer, but also the possibility of fine foreign matter entering into the hydraulic piping at the time of attachment/detachment of the piping rises. For this reason, in this rolling mill, it is not possible to employ servo valves for high response hydraulic control. Further, to facilitate detachment and reattachment of piping, it is necessary to use flexible structure, freely detachable hydraulic piping (flexible piping etc.) to connect to the hydraulic control valves. Further, if employing flexible piping, due to the flexible structure, sometimes fluctuations in the hydraulic pressure will end up being absorbed and eased. Therefore, it becomes difficult to provide high response roll bending devices.

[0015] On the other hand, the rolling mill which is disclosed in each of PLT's 2 and 4 (FIG. 13) has the increase bending devices 6-1 and 6-2 built into the project blocks 5-1 and 5-2 which are connected to the rolling mill housing 9. For this reason, the hydraulic piping of the increase bending devices does not have to be detached and reattached at each roll changing operation. Therefore, this rolling mill can be provided with high response roll bending devices. For this reason, it is frequently used for final rolling mills of hot strip mills.

However, this rolling mill supports the offset force component which acts on the upper work roll 1-1 and other rolling direction forces by the contact surfaces of the work roll chock 3-1 and project block 5-2. For this reason, if operating a reduction device 11 to increase the roll gap, the center of rotation of the work roll will become outside of the contact surfaces and the work roll chock 3-1 will become unstable in posture. As a result, a large roll gap cannot be obtained. For this reason, this rolling mill is hardly ever employed in a plate rolling mill where a large roll gap is required.

[0016] In the above way, in the prior art, there has never been a rolling mill which can obtain a large roll gap wherein high response, powerful work roll bending devices can be built in. The problem to be solved by the present invention is to provide a rolling mill which can obtain a large gap between upper and lower work rolls and which can impart a high response and powerful roll bending force.

Solution to Problem

[0017] The inventors engaged in intensive studies to solve the above problem and as a result discovered that by shifting the project blocks, which project from the housing in the inward direction, to below a pass line and setting them vertically asymmetrically with respect to the pass line, the following become possible:

(a) The rolling direction force which is applied to the upper work roll chock can be constantly received by the housing in this structure. Due to this, the work roll chock can be supported stably regardless of the roll gap.

(b) The project blocks may have upper and lower increase bending devices built into them. Due to this, large capacity/large stroke powerful bending devices can be provided.

(c) Further, by building increase bending devices into the project blocks, the hydraulic piping can be fixed in place and servo valves can be applied. Due to this, high response control of the increase bending force becomes possible.

Further, the inventors discovered that due to these device inventions, the following rolling mill operating method becomes possible.

(d) Even with low response decrease bending devices, cooperation with fast response increase bending devices enables high response bending force control. Due to this, the product quality and rolling yield are greatly improved.

The present invention was made based on these discoveries and has as its gist the following:

[0018] (1) A rolling mill of a metal flat-rolled product which has a pair of upper and lower work rolls and a pair of upper and lower backup rolls which support the same, which rolling mill of a metal flat-rolled product is characterized in that hydraulic cylinders which apply increase bending force to the upper and lower work rolls are arranged at project blocks which project to the inside of a rolling mill housing, rolling direction force which is applied to a lower work roll barrel is supported by contact surfaces of a project block and the lower work roll chock, and a rolling direction force which is applied to an upper work roll barrel is supported by contact surfaces of a rolling mill housing window which is positioned above the project blocks and the upper work roll chock.

In the above way, an "increase bending device" is a general term for a device including an actuator comprised of a hydraulic cylinder. However, in the present invention, for simplification of the explanation, an "increase bending device" will, unless otherwise stated, indicate the actuator comprised of a hydraulic cylinder.

[0019] (2) A rolling mill of a metal flat-rolled product as set forth in (1) characterized in that a hydraulic cylinder which applies increase bending force to the upper work roll and a hydraulic cylinder which applies increase bending force to the lower work roll are arranged at different positions in the project blocks when seen from a plan view.

[0020] (3) A rolling mill of a metal flat-rolled product as set forth in (1) or (2) characterized in that a hydraulic cylinder which applies decrease bending force to the upper work roll is arranged at an upper backup roll chock of the upper backup roll. Like with an increase bending device, in the present invention, a "decrease bending device" is a general term for a device including an actuator comprised of a hydraulic cylinder. However, in the present invention, for simplification of the explanation, a "decrease bending device" will, unless otherwise stated, indicate the actuator comprised of a hydraulic cylinder.

(4) A rolling mill of a metal flat-rolled product as set forth in any one of (1) to (3) characterized in that a hydraulic cylinder which applies decrease bending force to the lower work roll is arranged at the lower backup roll chock or at second project blocks which are positioned below the project blocks (for example, FIG, 4, 5-3 and 5-4).

[0021] (5) A rolling method of a metal flat-rolled product which uses a rolling mill of a metal flat-rolled product as set forth in (3), the rolling method of a metal flat-rolled product characterized by: Before the start of rolling, causing both an increase bending force and a decrease bending force to act and causing, as a composite force, a roll bending force corresponding to a roll balance force to act on work roll chocks.

After that, causing the decrease bending force to change to become a predetermined in-rolling decrease bending force while causing the increase bending force to change so that the composite force of the decrease bending force and the increase bending force maintains the roll balance force. This step can be eliminated if making the decrease bending force a predetermined in-rolling decrease bending force and making the increase bending force act on the work roll chocks so that the composite force of the decrease bending force and the increase bending force becomes the roll balance force.

After that, at the time of rolling start, continuing control for holding the decrease bending force at the predetermined in-rolling decrease bending force while making the increase bending force change and making the predetermined in-rolling work roll bending force act on the work roll chocks as the composite force.

During the rolling, performing the rolling so as to maintain said predetermined in-rolling work roll bending force,

after that, at the time of rolling end, making the increase bending force change, making a roll bending force which corresponds to the roll balance force act on the work roll chocks as a composite force with the decrease bending force, and ending the rolling of the metal flat-rolled product in that state.

After that, to maintain the composite force constituted by the roll balance force, reducing the decrease bending force and increase bending force. This step as well can be omitted if maintaining the decrease bending force at a predetermined in-rolling decrease bending force and if making the increase bending force act on the work roll chocks so that the composite force of the decrease bending force and the increase bending force becomes the roll balance force.

[0022] (6) A rolling method of a metal flat-rolled product as set forth in (5) characterized by measuring a hydraulic pressure inside of a hydraulic cylinder which generates the decrease bending force or inside hydraulic piping which leads to the hydraulic cylinder and by using the measured value as the basis to control the increasing bending force so that a roll bending force which acts on the work roll chocks as a composite force becomes a predetermined value.

Advantageous Effects of Invention

[0023] The rolling mill according to the present invention, as shown in FIG. 1, supports the rolling direction force which is applied to the barrel of the upper work roll 1-1 by the contact surfaces between the upper work roll chock 3-1 and the housing window above the project block 5-2 in structure. For this reason, a large roll gap can be obtained and a powerful roll bending force can also be obtained.

Further, there is no need to detach and reattach the hydraulic piping of the increase bending devices with each work roll changing operation. For this reason, it is possible to connect the increase bending devices through fixed hydraulic piping to respective hydraulic control valves, possible to employ servo valves for high response hydraulic control, and possible to provide high response increase bending devices.

[0024] In the rolling method according to present invention, even when low response decrease bending devices have to be provided, they can be compensated for by the high response increase bending devices so as to impart a high response and powerful crown/shape control function.

Therefore, even when the rolled material entry side thickness or the rolled material temperature or other parameters fluctuate during rolling, a good crown/shape can be built in despite these external disturbances and the product quality and yield can be greatly improved.

Brief Description of Drawings

[0025]

FIG. 1 is a side view which shows an example of the structure of a rolling mill according to the present invention.

FIG. 2 is a see-through plan view which shows an example of the arrangement of upper and lower increase bending devices.

FIG. 3 is a see-through plan view which shows an example of the arrangement of upper and lower increase bending devices.

FIG. 4 is a side view which shows another example of the structure of a rolling mill according to the present invention.

FIG. 5 is a view which shows an example of a flow of operation of a rolling method according to the present invention.

FIG. 6 is a view which shows changes along with time in a roll bending force etc. accompanying the flow of operation of FIG. 5.

FIG. 7 is a view which shows changes along with time in a roll bending force etc. in the case where a response of decrease bending devices is low.

FIG. 8 is a view which shows another example of a flow of operation of the rolling method according to the present invention.

FIG. 9 is a view which shows changes along with time in a roll bending force etc. accompanying the flow of operation of FIG. 8.

FIG. 10 is a side view which shows the structure of a rolling mill according to the prior art.

FIG. 11 is a side view which shows the structure of a rolling mill according to the prior art.

FIG. 12 is a side view which shows the structure of a rolling mill according to the prior art.

FIG. 13 is a side view which shows the structure of a rolling mill according to the prior art.

FIG. 14 is a side view which shows the structure of a rolling mill according to the prior art.

Description of Embodiments

[0026] Below, referring to FIGS. 1 to 13, a rolling mill according to the present invention and a rolling method which uses that rolling mill will be explained. FIG. 1 is a side view which shows one example of the structure of the rolling mill according to the present invention. As shown in this figure, the rolling mill according to the present invention is a rolling mill which is provided with a pair of upper and lower work rolls 1-1 and 1-2 and a pair of upper and lower backup rolls 2-1 and 2-2 which support the same.

Further, the rolling mill according to the present invention is a rolling mill which arranges upper increase bending devices 6-1 and 6-2 which apply increase bending force to the upper work roll 1-1 and lower increase bending devices 6-3 and 6-4 which apply increase bending force to the lower work roll 1-2 at project blocks 5-1 and 5-2 which project to the inside of the housing 9.

[0027] This point is the same as a conventional rolling mill which is shown in FIG. 13. However, the rolling mill according to the present invention fundamentally reevaluates this to solve the problem in the conventional rolling mill which is shown in FIG. 13. That is, it changes the positions of the project blocks 5-1 and 5-2, the shape of the upper work roll chock 3-1, etc. from the viewpoint of the structural design of the rolling mill, in particular from the viewpoint of obtaining a large roll gap.

[0028] In the conventional rolling mill which is shown in FIG. 13, a large roll gap cannot be obtained. This rolling mill arranges the project blocks 5-1 and 5-2 to be substantially vertically symmetrical with the position through which the rolled material 10 passes (pass line). For this reason, the contact surfaces where the upper work roll chock 3-1 and the project block 5-2 contact can be used to support the offset force component or other rolling direction force which acts on the upper work roll 1-1, that is, the rolling direction force which is applied from the rolled material 10, the upper backup roll 2-1, etc. to the barrel of the upper work roll 1-1. In this structure, as the roll gap is made larger, the position of the center of rotation of the upper work roll 1-1 (the working point of the rolling direction force) and the upper work roll chock 3-1 move upward and the contact surface area with the project block 5-2 which supports the rolling direction force is decreased. Therefore, as the roll gap is made larger, the upper work roll chock 3-1 becomes unstable in posture and a large roll gap cannot be obtained.

[0029] The rolling mill according to the present invention solves the above problem. The rolling mill according to the present invention, as shown in FIG. 1, arranges the project blocks 5-1 and 5-2 which project from the housing 9 in the inside direction at positions shifted to below the pass line. That is, unlike in the conventional rolling mill which is shown in FIG. 13, the project blocks 5-1 and 5-2 are arranged vertically asymmetrically with respect to the pass line. Furthermore, the upper work roll chock 3-1 does not contact the project block 5-2 to support the rolling force, but contacts the housing window to support the rolling force.

[0030] Due to this, in the rolling mill according to the present invention, the contact surfaces of the upper work roll chock 3-1 and the housing window 12 above the project block 5-2 are used to support the offset force component and other rolling direction force which acts on the upper work roll 1-1, that is, the rolling direction force which is applied from the rolled material 10, the upper backup roll 2-1, etc. to the barrel of the upper work roll 1-1.

According to such a structure, even if operating the reduction device 11 of the rolling mill to increase the roll gap, the area by which the upper work roll chock 3-1 and the housing window contact does not change at all. Therefore, the upper work roll chock 3-1 is constantly held stably in posture regardless of the roll gap.

[0031] As shown in FIG. 13, a rolling mill which has upper and lower increase bending devices arranged at the project blocks is known. However, the rolling mill according to the present invention fundamentally reevaluates the positions of the project blocks 5-1 and 5-2 and the shape of the upper work roll chock 3-1 so as to support the rolling direction force which is applied to the barrel of the upper work roll 1-1 by the contact surfaces between the upper work roll chock 3-1 and the housing window 12 above the project block 5-2 in structure, so a large roll gap can be obtained.

Further, in the rolling mill according to the present invention, upper increase bending devices 6-1 and 6-2 which apply increase bending force to the upper work roll 1-1 and lower increase bending devices 6-3 and 6-4 which apply increase bending force to the lower work roll 1-2 are arranged at the project blocks 5-1 and 5-2 which project to the inside of the housing 9. For this reason, there is no need to detach and reattach the hydraulic piping of the increase bending devices with each work roll changing operation and high response increase bending devices can be employed. This is because it is possible to connect them through fixed hydraulic piping to respective hydraulic control valves, and servo valves for high response hydraulic control can be employed.

[0032] Note that, in the rolling mill according to the present invention, the rolling direction force which is applied to the barrel of the lower work roll 1-2 is supported by the contact surfaces between the lower work roll chock 3-2 and the project block 5-2. For this reason, the rolling mill according to the present invention which is shown in FIG. 1 increases the height of the part of the lower work roll chock 3-2 which is sandwiched between the project blocks 5-1 and 5-2. Further, the roll gap is mainly adjusted by making the upper work roll chock move up and down, so there is little up and down movement of the lower work roll chock. For this reason, there is no destabilization of the posture of the lower work roll as the roll gap becomes larger.

[0033] FIG. 2 is a cross-sectional plan view which shows an example of the arrangement of the upper and lower increase bending devices. That is, it is a cross-sectional view of the pass line heights of the project blocks 5-1 and 5-2.

In the rolling mill according to the present invention, the upper and lower increase bending devices are preferably arranged offset from each other in the cross-sectional plan view of the project blocks. For example, as shown in FIG. 2, the upper increase bending devices 6-1 and 6-2 and the lower increase bending devices 6-3 and 6-4 are preferably arranged to a positional relationship where they are shifted in the axial direction of the work roll 1-2. By doing this, the upper and lower increase bending devices will not interfere with each other. It is possible to increase the strokes of the upper increase bending devices 6-1 and 6-2 and obtain a further larger roll gap.

Note that, in FIG. 2, the lower increase bending devices 6-3 and 6-4 are respectively comprised of two hydraulic cylinders at the entry side and the exit side. However, similar effects can be obtained by using single hydraulic cylinders and arranging them at different positions in the axial direction of the work roll 1-2 so as not to interfere with the upper increase bending devices 6-1 and 6-2.

[0034] FIG. 3 is a cross-sectional plan view which shows an example of the arrangement of the upper and lower increase bending devices. That is, it is a cross-sectional view of the pass line height of the project blocks 5-1 and 5-2. As shown in this figure, the upper increase bending devices 6-1 and 6-2a and the lower increase bending devices 6-3 and 6-4 may be arranged in a positional relationship shifted in the rolling direction. With this arrangement as well, the upper and lower increase bending devices do not interfere with each other. It is possible to increase the strokes of the upper increase bending devices 6-1 and 6-2 to obtain a further larger roll gap.

[0035] Up to here, the structure of the rolling mill according to the present invention has been explained mainly from the viewpoint of one of the problems to be solved, that is, obtaining a large roll gap. Next, it will be explained that according to this structure, another problem, that is, imparting a powerful roll bending force, can also be easily solved.

[0036] FIG. 10 and FIG. 11 are both rolling mills according to the prior art. Each rolling mill enables a large roll gap to be obtained.

However, in these conventional rolling mills, a powerful roll bending force cannot be imparted. This is because the arm parts which project out from the upper backup roll chock 4-1 downward have the upper increase bending devices 6-1 and 6-2 built into them in structure, so large capacity and large stroke upper increase bending devices 6-1 and 6-2 cannot be provided. Further, these rolling mills have arm parts extending from the upper backup roll chocks, so the installation spaces of the upper decrease bending devices end up near the axial centers of the rolls. For this reason, the arm parts interfere with the bearings of the upper backup rolls, so large capacity upper decrease bending devices 7-1 and 7-2 cannot be provided.

[0037] On the other hand, as shown in FIG. 1, in the rolling mill according to the present invention, project blocks 5-1 and 5-2, which project from the housing 9 of the rolling mill in the inside direction, are provided with large capacity/large stroke upper increase bending devices 6-1 and 6-2.

Further, the rolling mill according to the present invention does not provide the upper backup roll chock 4-1 with arm parts like the rolling mills which are shown in FIG. 10 and FIG. 11. For this reason, large capacity upper decrease bending devices 7-1 and 7-2 can be provided at positions of the upper backup roll chock 4-1 which do not interfere with the bearings of the upper backup roll. Due to this, the upper work roll 1-1 can be given a large decrease bending force.

[0038] That is, according to the rolling mill according to the present invention, which fundamentally reevaluates the positions of the project blocks 5-1 and 5-2 and the shape of the upper work roll chock 3-1 and is structured to support the rolling direction force which is applied to the barrel of the upper work roll 1-1 by the contact surfaces of the upper work roll chock 3-1 and the housing window 12, a large roll gap can be obtained and a powerful roll bending force can be imparted. Further, there is no need to detach and reattach hydraulic piping of the increase bending devices with each work roll changing operation. For this reason, it is possible to connect hydraulic control valves to the increase bending devices 6-1 to 6-4 through fixed hydraulic piping and possible to employ servo valves for high response hydraulic control. Therefore, it is possible to provide high response increase bending devices.

[0039] FIG. 4 is a side view which shows another example of the rolling mill according to the present invention. The rolling mill which is shown in FIG. 4 has an upper roll system configured the same as in FIG. 1, but has a lower roll system configured differently. The rolling mill which is shown in FIG. 1 is provided at the lower backup roll chock 4-2 with lower decrease bending devices 7-3 and 7-4 which apply decrease bending force to the lower work roll. As opposed to this, the rolling mill which is shown in FIG. 4 provides the lower decrease bending devices 7-3 and 7-4 at the special project blocks 5-3 and 5-4 which are positioned below the project blocks 5-1 and 5-2.

[0040] In this regard, if, like in the rolling mill which is shown in FIG. 1, providing the lower decrease bending devices 7-3 and 7-4 at the lower backup roll chock 4-2, when changing the lower backup roll 2-2, it is necessary to detach and reattach the hydraulic piping of the decrease bending devices. That is, there is a high possibility of minute foreign matter entering the hydraulic piping at the time of detachment and reattachment.

For this reason, in general, it becomes difficult to employ servo valves for high response hydraulic control and sometimes is necessary to employ flexible piping for some parts.

Therefore, compared to when employing fixed piping and servo valves, the response of the roll bending devices has to become lower.

[0041] As opposed to this, according to the rolling mill which is shown in FIG. 4, the above problem which occurs when changing the lower backup roll 2-2 can be solved. This is because it is possible to employ servo valves for high response hydraulic control for the hydraulic piping of the lower decrease bending devices which are provided at the specialized project blocks and flexible piping need not be used. For this reason, change of the lower backup roll 2-2 becomes easy and high response roll bending devices can be provided.

[0042] Next, the rolling method according to present invention will be explained. As shown in FIG. 1 and FIG. 4, when arranging the upper decrease bending devices 7-1 and 7-2 at the upper backup roll chock 4-1, when changing the upper backup roll 2-1, the hydraulic piping of the decrease bending devices has to be detached and reattached. At the time of detachment and reattachment, there is a high possibility of minute foreign matter entering into the hydraulic piping.

For this reason, in general, it becomes relatively difficult to employ servo valves for high response hydraulic control. Further, to facilitate detachment and reattachment of piping, it is necessary to use flexible structure, freely detachable hydraulic piping such as flexible piping etc. to connect to the hydraulic control valves. Further, if employing flexible piping or other flexible structure, freely detachable hydraulic piping, due to the flexible structure, sometimes fluctuations in the hydraulic pressure will end up being absorbed and eased.

Therefore, when trying to provide the upper decrease bending devices 7-1 and 7-2 at the upper backup roll chock 4-1, compared with when employing fixed piping and servo valves, the response of the roll bending devices has to become lower.

[0043] In this regard, the decrease bending force cannot be applied at the time of idling when no rolling load is being applied. For this reason, when applying a decrease bending force, it is necessary to quickly set the decrease bending force in the interval from the idling state where a roll balance is obtained to the start of rolling and further to quickly return to the roll balance state at the time of rolling end. Therefore, if changing the roll bending force by control by inferior response decrease bending devices, there is a possibility that the predetermined decrease bending force will not be applied at the tip and tail ends of the rolled material and the parts with defective shapes will become longer.

[0044] The rolling method according to present invention solves the above problem. That is, this is a rolling method which uses a rolling mill according to the present invention which arranges upper decrease bending devices 7-1 and 7-2 at the upper backup roll chock 4-1 and solves the above problems which can occur in that rolling mill.

[0045] In the above way, in a rolling mill which provides upper decrease bending devices 7-1 and 7-2 at the upper backup roll chock 4-1, sometimes the decrease bending devices become poor in response.

However, in the rolling mill according to the present invention, the project blocks 5-1 and 5-2 which project from the housing 9 to the inside direction are provided with upper increase bending devices 6-1 and 6-2 in structure, so these can be made large capacity/large stroke upper increase bending devices 6-1 and 6-2. Further, it is not necessary to detach and reattach the hydraulic piping of the increase bending devices with each roll changing operation, so it is possible to employ fixed hydraulic piping and servo valves. Due to this, it is possible to provide high response increase bending devices.

The rolling method according to present invention changes the roll bending forces at the time of rolling start and at the time of rolling end by using the high response increase bending devices and compensates for the response of the decrease bending devices when making the decrease bending force act on the work rolls for the purpose of crown/shape control.

[0046] FIG. 5 is a view which shows one example of the flow of operation of the rolling method according to present invention. That is, it is a view which shows the flow of operation of a high response increase bending device and a somewhat lower response decrease bending device.

Further, FIG. 6 shows the changes along with time in the roll bending force etc. for a single rolled material in this rolling method. FIG. 6 shows, from the top, the changes along with time in the rolling load, output of an increase bending device, output of a decrease bending device, and the composite force of the same, that is, the work roll bending force. Below, this will be explained based on FIGS. 5 and 6.

First, before the start of rolling, the set value F_R of the rolling work roll bending force corresponding to the rolled material to be next rolled is calculated and output. Here, assume that F_R is calculated as a negative value, that is, a decrease bending force. Note that, in the present invention, an increase bending force (force in increase direction (direction opening up rolls)) is made a positive value, while a decrease bending force (for in decrease direction (direction pressing upper and lower work rolls against each other)) is made a negative value.

[0047] Before the start of rolling, both the increase bending force and decrease bending force are made to act and the composite force constituted by the increase side roll bending force corresponding to the roll balance force (F_B) acts on the work roll chock.

That is, at the timing of idling before rolling, the increase bending device output is made I_B (>0), the decrease bending device output is made D_B (<0), and I_B+D_B acts as the roll balance force F_B (>0).

The roll balance force F_B is determined as the force by which the work roll which is driven by the electric motor and the backup roll which is driven by that roll do not slip even at the time of the idling state. At this time, D_B should be set by the minimum hydraulic pressure of an extent where the actuator of the decrease bending device does not end up separating from the work roll chock.

[0048] Further, at a certain timing before the start of rolling (point a on time axis), a predetermined in-rolling decrease bending device output D_S sufficient for making the in-rolling work roll bending force F_R act is calculated by $D_S=F_R-I_R$. Further, D_S and I_S are simultaneously output so that the roll balance force (F_B) becomes constant. Here, I_R is the increase bending device output during rolling. A value close to the minimum value of possible control is determined in advance so that the absolute value of D_S does not become excessive. I_S is the increase bending device output which becomes $I_S+D_S=F_B$. Therefore, at the set timing, the composite force constituted by the work roll bending force remains at F_B and does not substantially change.

[0049] Next, at the time of rolling start, the decrease bending force is held at a constant value while the increase bending force is lowered and the composite force constituted by the predetermined in-rolling work roll bending force F_R acts on the work roll chock.

That is, at the time of rolling start (point b on the time axis), the increase bending device output is changed from Is to I_R. By doing this, the slow response decrease bending device output is left as D_S while the fast response increase bending device can be controlled to quickly switch the composite force constituted by the work roll bending force from the roll balance force (F_B(>0)) to the in-rolling work roll bending force (F_R(<0)).

Note that, "the time of rolling start (b)" indicates the point of time of start of rolling. This may be detected for example by the method of finding the time when the load which is detected by a load cell for measurement of the rolling load of a rolling mill exceeds 30% of a predicted rolling load.

[0050] Further, at the time of rolling end, the roll bending force is returned to the state before the start of rolling by making a roll bending force which corresponds to the composite force constituted by the roll balance force (F_B) act on the work roll chock and ending the rolling.

That is, at the time of rolling end (point c on time axis), the decrease bending device output is left as D_S while the fast response increase bending device output is made to change from I_R to I_S. By doing this, the composite force constituted by the work roll bending force can be quickly switched from the in-rolling work roll bending force (F_R(<0)) to the roll balance force (F_B(>0)).

Note that, "the time of rolling end (c)" indicates the point of time of ending the rolling end. This may be detected for example by the method of finding the time when the load which is detected by a load cell for measurement of the rolling load of a rolling mill falls under 50% of an average value of measured rolling load.

[0051] Further, the point of time after the elapse of for example 1 to 3 seconds from the time of rolling end (c) is made the timing of work completion (point d on time axis). At this timing, the increase bending device output is changed to I_B and the decrease bending device output is changed to D_B. Even with this change, the composite force constituted by the work roll bending force is maintained at substantially the roll balance force (F_B).

[0052] As shown in FIGS. 5 and 6, in the rolling method according to present invention, at the time of rolling start and at the time of rolling end, the roll bending force is changed by using high response increase bending devices. For this reason, even if relatively low response decrease bending devices have to be provided, they are compensated for by the high response increase bending devices, so a high response and powerful crown/shape control function can be imparted.

Further, even when various factors (outside disturbances) cause the rolling load to change during rolling, quick control to make the high response increase bending devices maintain the optimal work roll bending force is possible. In this case, control should be performed to make the in-rolling work roll bending force change, for example, in accordance with the measured value of the rolling load. That is, according to the rolling method according to present invention, even when the rolled material entry side thickness or the rolled material temperature or other parameters fluctuate during rolling, a good crown/shape can be built in despite these external disturbances. Due to this, the product quality and yield can be greatly improved.

[0053] FIG. 7 is a view which shows the changes along with time in the rolling bending force etc. in the case of a low response of the decrease bending device (in particular, in the case of having hydraulic pressure characteristics whereby if the reaction force is withdrawn, the pressure ends up falling). In the same way as FIG. 6, this shows the changes along with time in the roll bending force etc. which accompany a rolling operation on a single rolled material in accordance with the flow of operation of the increase bending device and the decrease bending device which is shown in FIG. 5. That is, compared with the case of FIGS. 5 and 6, the example of a case of a slow speed of response of the decrease bending device is shown.

[0054] In the case of FIG. 7, at the timings b and c, the output of the high response increase bending device rapidly changes, so the output of the poor response decrease bending device fluctuates. As a result, the composite force constituted by the work roll bending force is slow to reach F_R at the timing b and is slow to reach F_B at the timing c. The rolling method which is shown in FIG. 8 solves this problem.

[0055] FIG. 8 is a view which shows the flow of operation in the case where there is a fast response increase bending device and a slow response decrease bending device. Below, this will be explained based on the drawing.

In the rolling method which is shown in FIG. 8, a load cell which is set at the decrease bending device is used to constantly measure the decrease bending force or the hydraulic pressure inside of the hydraulic piping which leads to that device. This measured value is used as the basis to control the increase bending device. That is, the output of the increase bending device is controlled in accordance with the decrease bending force or hydraulic pressure of the decrease bending device so that the work roll bending force becomes the roll balance force F_B before and after rolling and the work roll bending force becomes F_R during rolling. Note that the rest of the control is similar to the rolling method which is shown in FIG. 5.

By rolling by the rolling method which is shown in FIG. 8, as shown in FIG. 9, it is possible for fluctuations in output of the decrease bending device to be compensated for by the increase bending device and for the work roll bending force to be optimally controlled with a high response.

Further, even without measuring the decrease bending force during rolling or feedback control by measurement of the hydraulic pressure, it is possible to obtain similar effects by predicting in advance the fluctuations in output of the decrease bending device and setting the output of the increase bending device to compensate for this.

Industrial Applicability

[0056] The present invention can be utilized for rolling of steel plate, in particular for reverse rolling mills which require particularly large gaps etc.

Reference Signs List

[0057]

1-1. upper work roll
1-2. lower work roll
2-1. upper backup roll
2-2. lower backup roll
3-1. upper work roll chock
3-2. lower work roll chock
4-1. upper backup roll chock
4-2. lower backup roll chock
5-1. entry side project block
5-2. exit side project block
5-3. entry side lower project block
5-4. exit side lower project block
6-1. entry side upper increase bending device
6-2. exit side upper increase bending device
6-3. entry side lower increase bending device
6-4. exit side lower increase bending device
7-1. entry side upper decrease bending device

7-2. exit side upper decrease bending device
7-3. entry side lower decrease bending device
7-4. exit side lower decrease bending device
8-1. entry side backup roll balancing device
8-2. exit side backup roll balancing device
9. housing
10. rolled material
11. reduction device
12. housing window

Claims

1. A rolling mill of a metal flat-rolled product which has a pair of upper and lower work rolls and a pair of upper and lower backup rolls which support the same, which rolling mill of a metal flat-rolled product is **characterized in that**
hydraulic cylinders which apply increase bending force to the upper and lower work rolls are arranged at project blocks which project to the inside of a rolling mill housing,
rolling direction force which is applied to a lower work roll barrel is supported by contact surfaces of a project block and the lower work roll chock, and
rolling direction force which is applied to an upper work roll barrel is supported by contact surfaces of a rolling mill housing window which is positioned above the project blocks and the upper work roll chock.

2. A rolling mill of a metal flat-rolled product as set forth in claim 1 **characterized in that** a hydraulic cylinder which applies increase bending force to the upper work roll and a hydraulic cylinder which applies increase bending force to the lower work roll are arranged at different positions in the project blocks when seen on a plan view.

3. A rolling mill of a metal flat-rolled product as set forth in claim 1 or 2 **characterized in that** a hydraulic cylinder which applies decrease bending force to the upper work roll is arranged at an upper backup roll chock of the upper backup roll.

4. A rolling mill of a metal flat-rolled product as set forth in any one of claims 1 to 3 **characterized in that** a hydraulic cylinder which applies decrease bending force to the lower work roll is arranged at the lower backup roll chock or at second project blocks which are positioned below the project blocks.

5. A rolling method of a metal flat-rolled product which uses a rolling mill of a metal flat-rolled product as set forth in claim 3, the rolling method of a metal flat-rolled product **characterized by**:

before the start of rolling, causing both an increase bending force and a decrease bending force to act and causing, as a composite force, a roll bending force corresponding to a roll balance force to act on work roll chocks;
after that, at the time of rolling start, continuing control for holding the decrease bending force at the predetermined in-rolling decrease bending force while making the increase bending force change and making the predetermined in-rolling work roll bending force act on the work roll chocks as the composite force;
during the rolling, performing the rolling so as to maintain said predetermined in-rolling work roll bending force; and
after that, at the time of rolling end, making the increase bending force change, making a roll bending force which corresponds to the roll balance force act on the work roll chocks as a composite force with the decrease bending force, and ending the rolling of the metal flat-rolled product in that state.

6. A rolling method of a metal flat-rolled product as set forth in claim 5, **characterized by** measuring a hydraulic pressure inside of a hydraulic cylinder which generates the decrease bending force or inside hydraulic piping which leads to the hydraulic cylinder and by using the measured value as the basis to control the increasing bending force so that a roll bending force which acts on the work roll chocks as a composite force becomes a predetermined value.

Fig.1

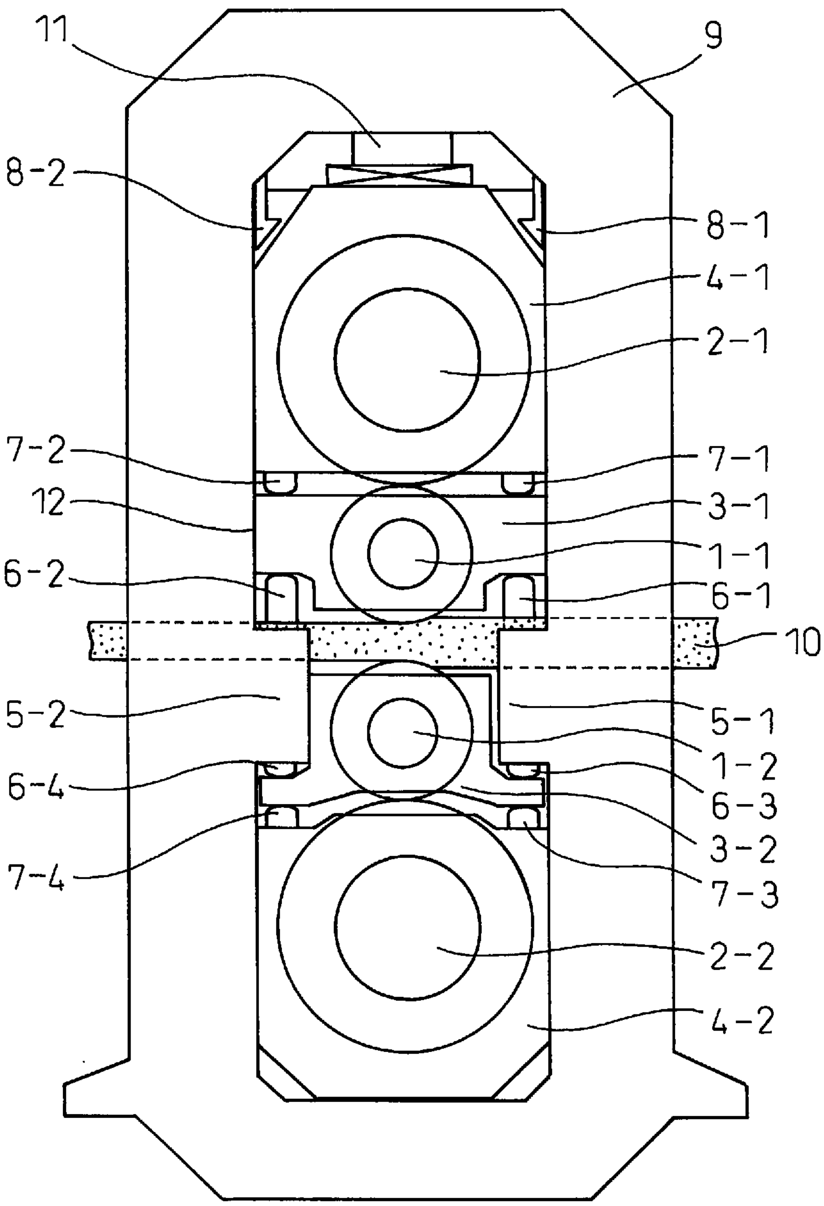


Fig.2

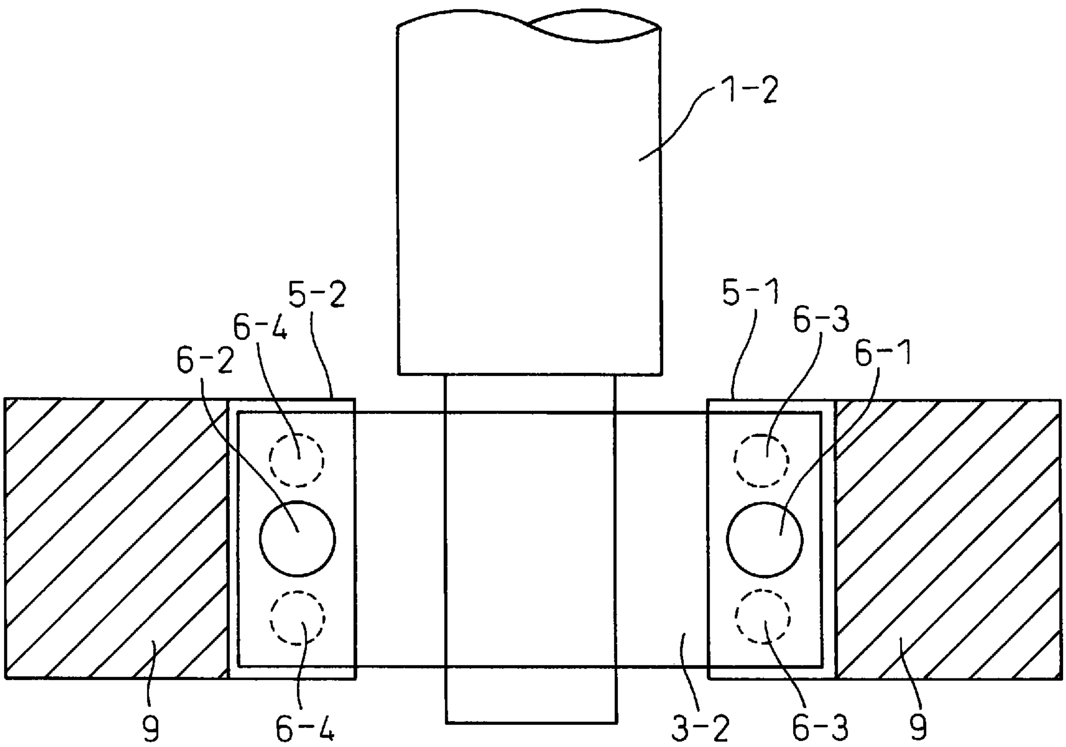


Fig.3

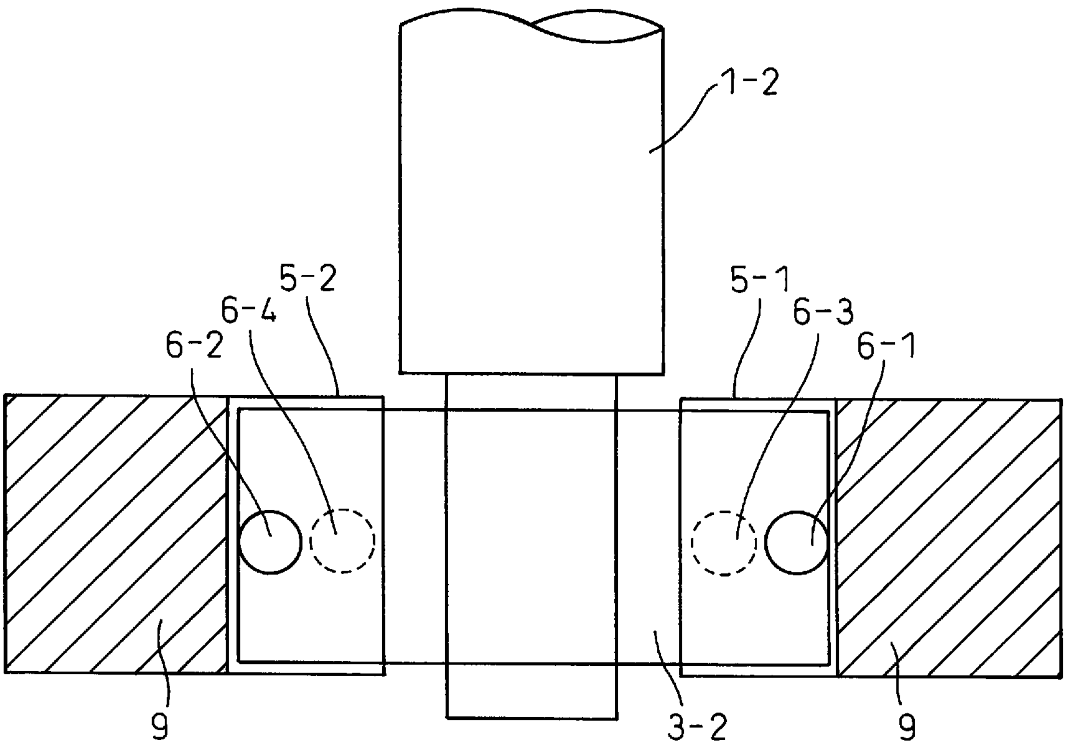
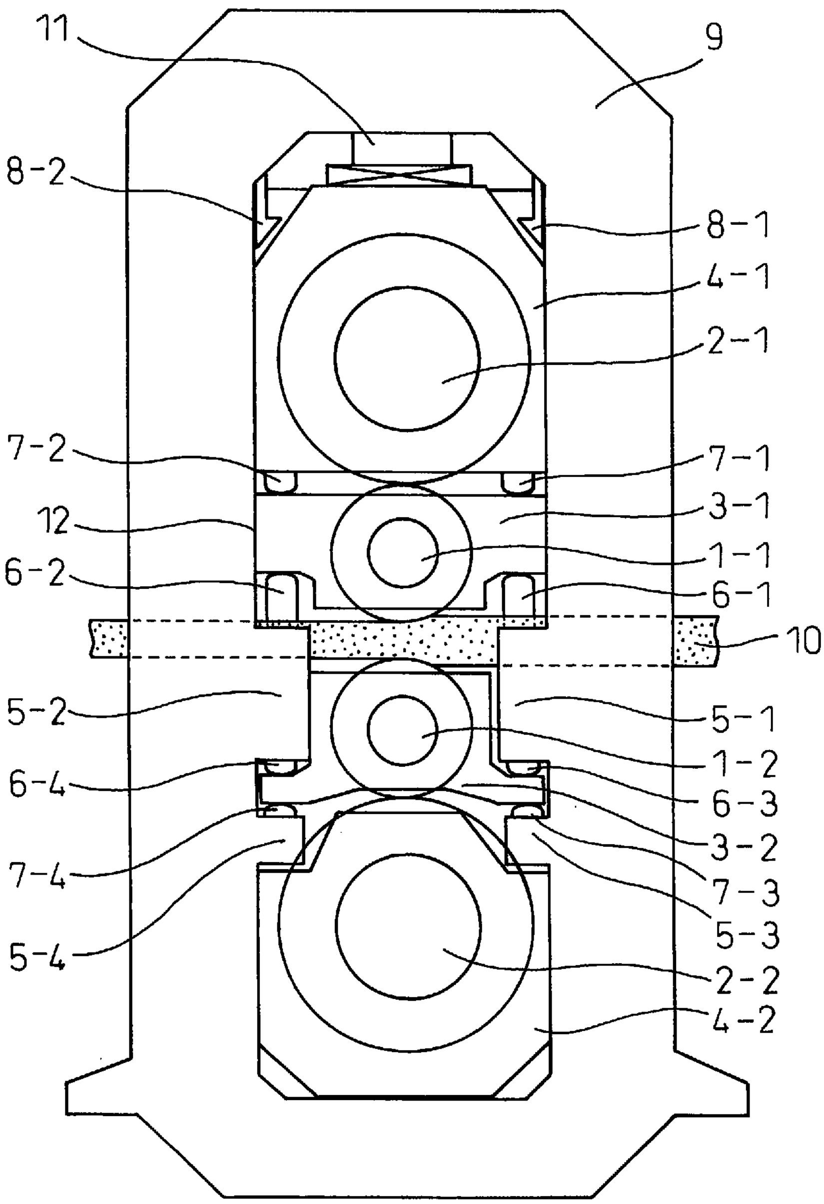


Fig.4


11
9
8-2
8-1
4-1
2-1
7-2
7-1
12
3-1
1-1
6-2
6-1
10
5-2
5-1
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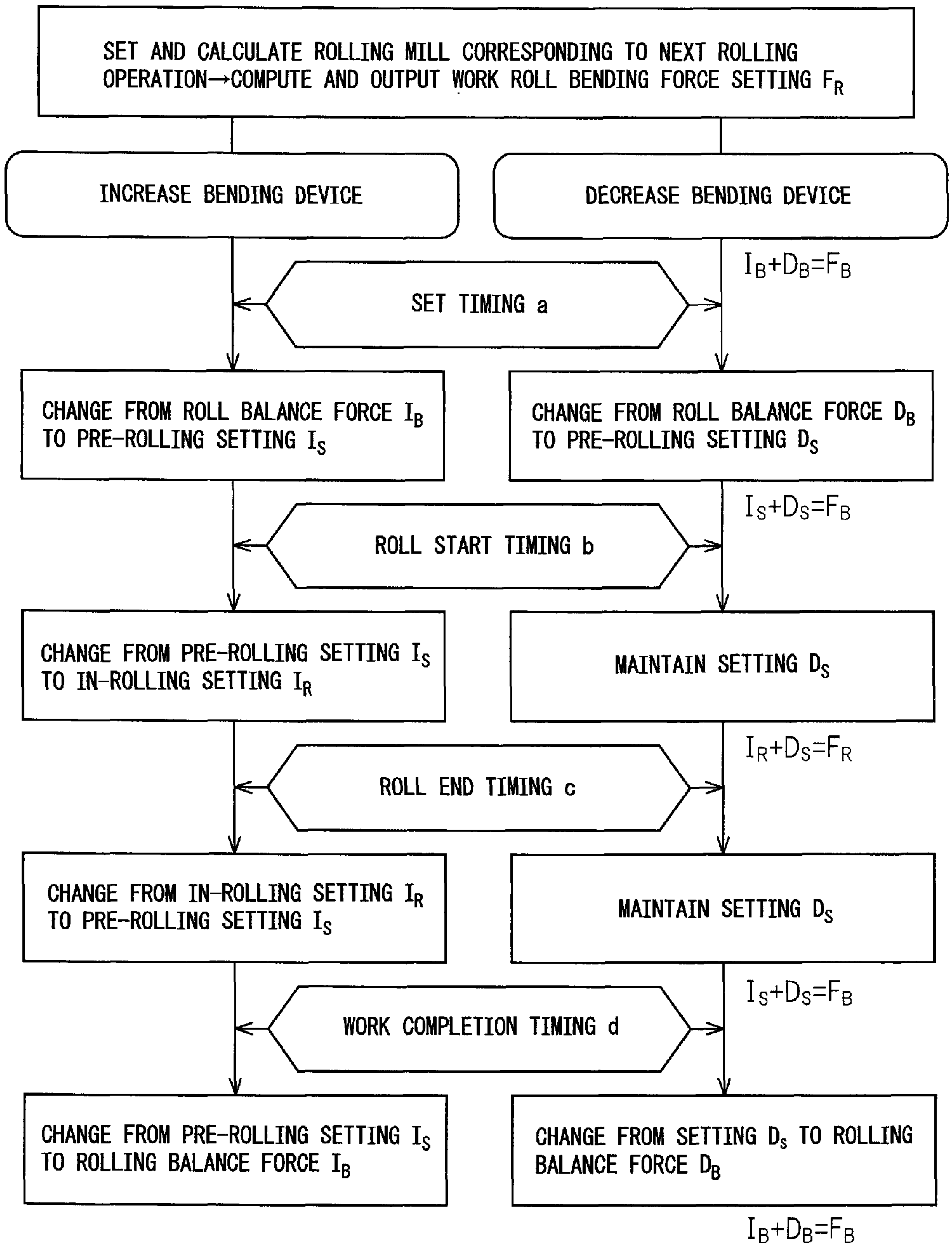
3-2
7-4
7-3
5-3
5-4
2-2
4-2

Fig.5



SET AND CALCULATE ROLLING MILL CORRESPONDING TO NEXT ROLLING OPERATION→COMPUTE AND OUTPUT WORK ROLL BENDING FORCE SETTING F_R
INCREASE BENDING DEVICE
DECREASE BENDING DEVICE
$I_B+D_B=F_B$
SET TIMING a
CHANGE FROM ROLL BALANCE FORCE I_B TO PRE-ROLLING SETTING I_S
CHANGE FROM ROLL BALANCE FORCE D_B TO PRE-ROLLING SETTING D_S
$I_S+D_S=F_B$
ROLL START TIMING b
CHANGE FROM PRE-ROLLING SETTING I_S TO IN-ROLLING SETTING I_R
MAINTAIN SETTING D_S
$I_R+D_S=F_R$
ROLL END TIMING c
CHANGE FROM IN-ROLLING SETTING I_R TO PRE-ROLLING SETTING I_S
MAINTAIN SETTING D_S
$I_S+D_S=F_B$
WORK COMPLETION TIMING d
CHANGE FROM PRE-ROLLING SETTING I_S TO ROLLING BALANCE FORCE I_B
CHANGE FROM SETTING D_S TO ROLLING BALANCE FORCE D_B
$I_B+D_B=F_B$

Fig.6

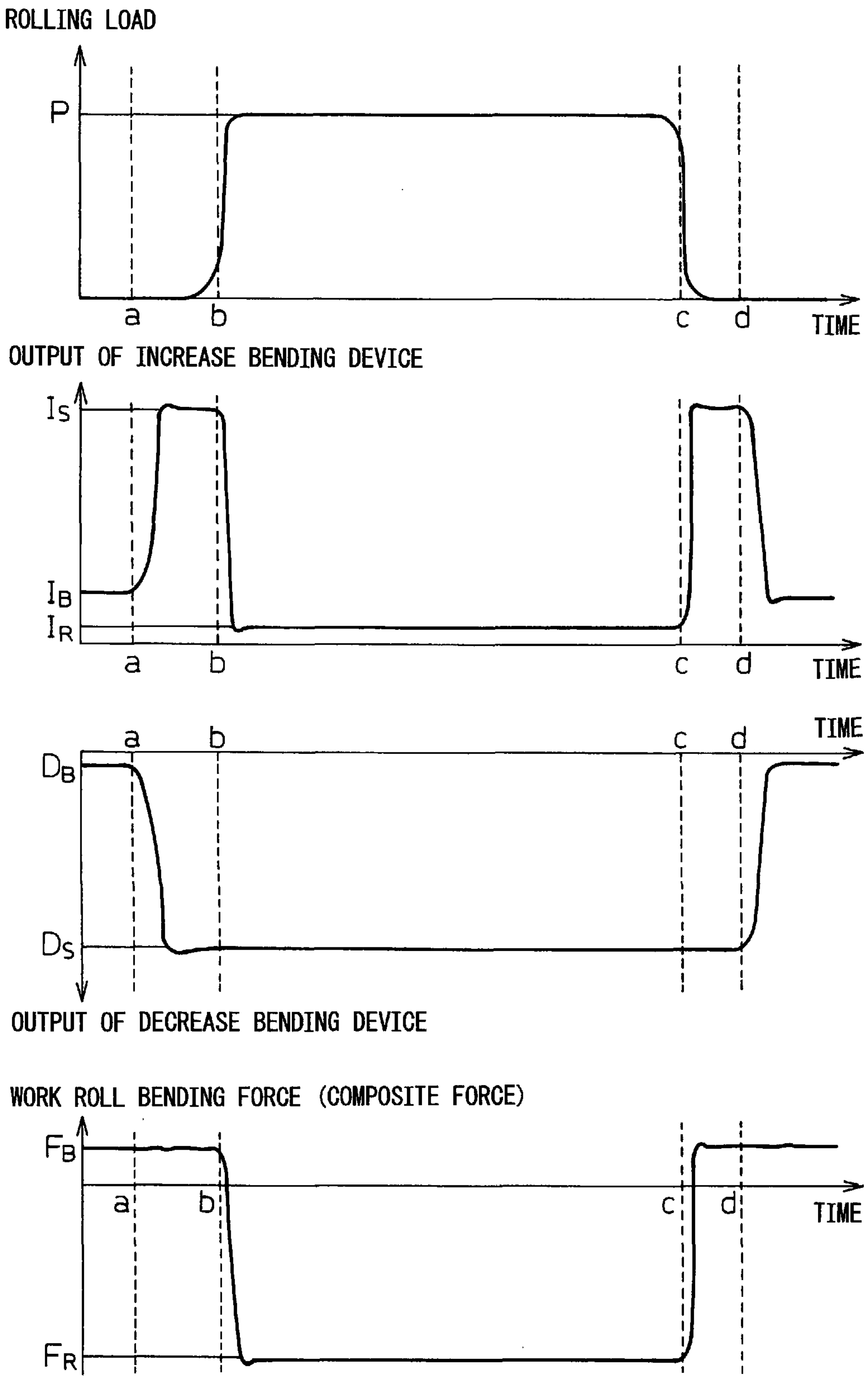
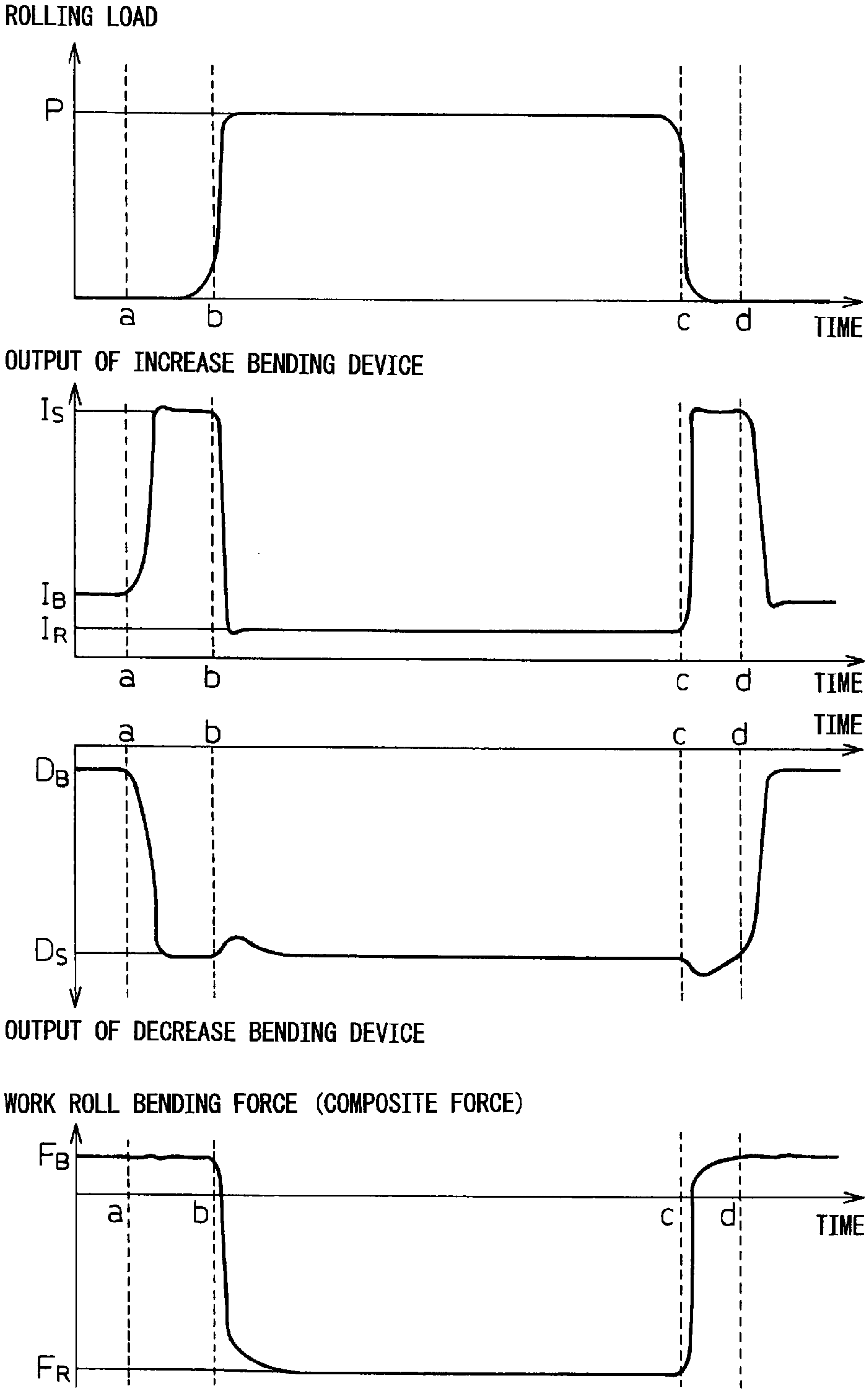

ROLLING LOAD
P
a
b
c
d
TIME
OUTPUT OF INCREASE BENDING DEVICE
I_S
I_B
I_R
a
b
c
d
TIME
a
b
c
d
TIME
D_B
D_S
OUTPUT OF DECREASE BENDING DEVICE
WORK ROLL BENDING FORCE (COMPOSITE FORCE)
F_B
a
b
c
d
TIME
F_R

Fig.7


ROLLING LOAD
P
a
b
c
d
TIME
OUTPUT OF INCREASE BENDING DEVICE
Is
IB
IR
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b
c
d
TIME
a
b
c
d
TIME
DB
DS
OUTPUT OF DECREASE BENDING DEVICE
WORK ROLL BENDING FORCE (COMPOSITE FORCE)
FB
a
b
c
d
TIME
FR

Fig.8

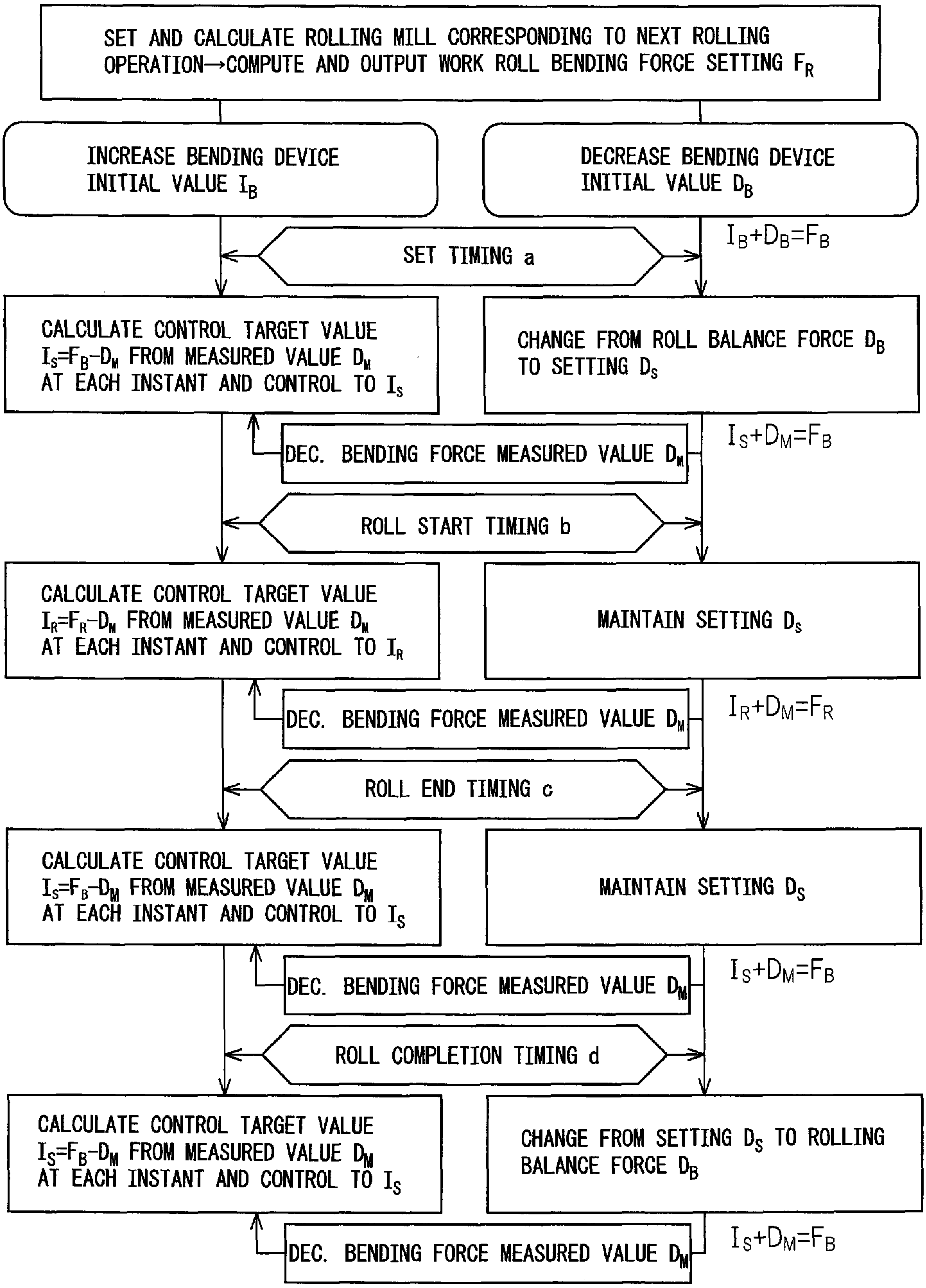

SET AND CALCULATE ROLLING MILL CORRESPONDING TO NEXT ROLLING OPERATION→COMPUTE AND OUTPUT WORK ROLL BENDING FORCE SETTING F_R
INCREASE BENDING DEVICE INITIAL VALUE I_B
DECREASE BENDING DEVICE INITIAL VALUE D_B
$I_B+D_B=F_B$
SET TIMING a
CALCULATE CONTROL TARGET VALUE $I_S=F_B-D_M$ FROM MEASURED VALUE D_M AT EACH INSTANT AND CONTROL TO I_S
CHANGE FROM ROLL BALANCE FORCE D_B TO SETTING D_S
DEC. BENDING FORCE MEASURED VALUE D_M
$I_S+D_M=F_B$
ROLL START TIMING b
CALCULATE CONTROL TARGET VALUE $I_R=F_R-D_M$ FROM MEASURED VALUE D_M AT EACH INSTANT AND CONTROL TO I_R
MAINTAIN SETTING D_S
DEC. BENDING FORCE MEASURED VALUE D_M
$I_R+D_M=F_R$
ROLL END TIMING c
CALCULATE CONTROL TARGET VALUE $I_S=F_B-D_M$ FROM MEASURED VALUE D_M AT EACH INSTANT AND CONTROL TO I_S
MAINTAIN SETTING D_S
DEC. BENDING FORCE MEASURED VALUE D_M
$I_S+D_M=F_B$
ROLL COMPLETION TIMING d
CALCULATE CONTROL TARGET VALUE $I_S=F_B-D_M$ FROM MEASURED VALUE D_M AT EACH INSTANT AND CONTROL TO I_S
CHANGE FROM SETTING D_S TO ROLLING BALANCE FORCE D_B
DEC. BENDING FORCE MEASURED VALUE D_M
$I_S+D_M=F_B$

Fig.9

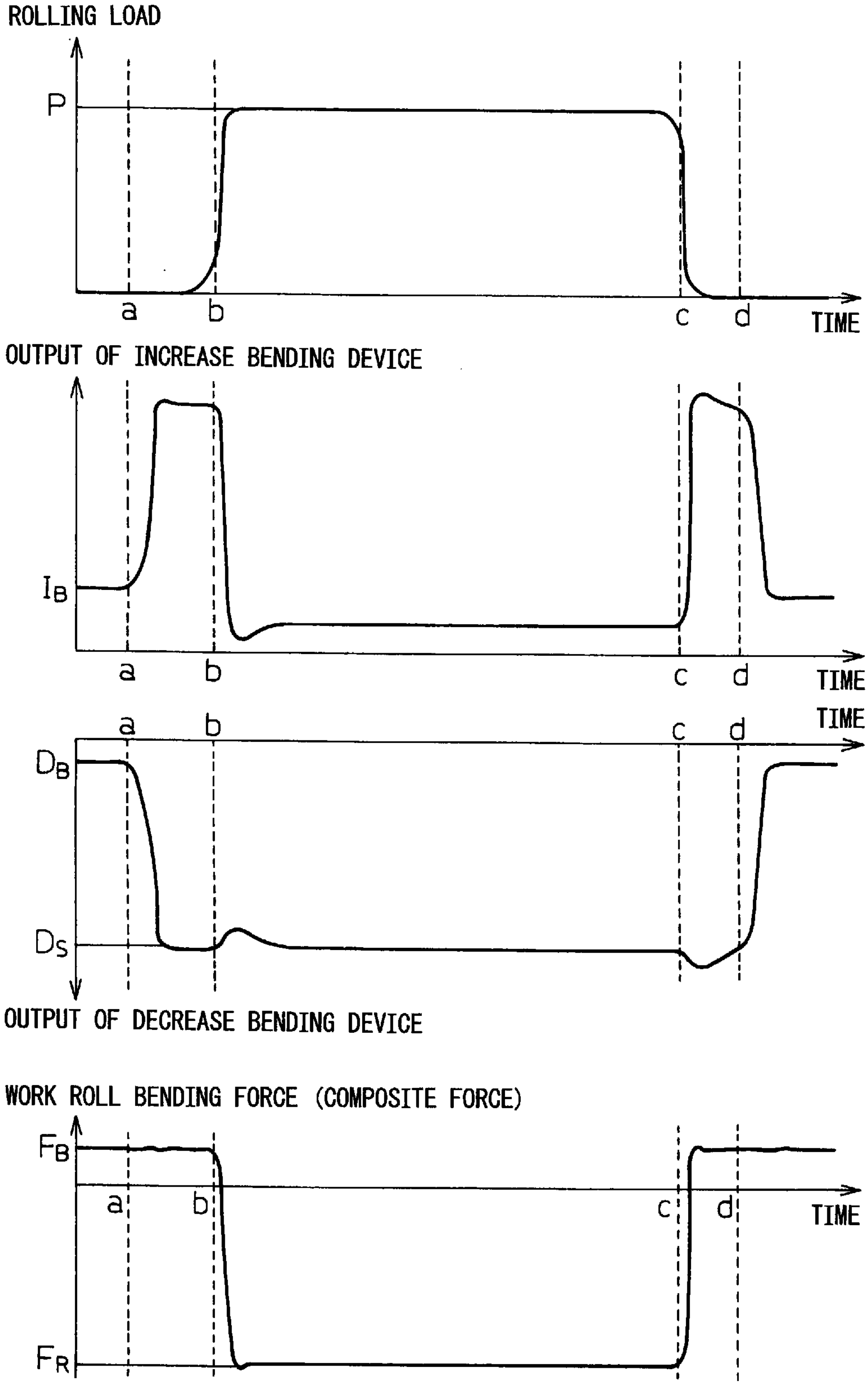

ROLLING LOAD
P
a
b
c
d
TIME
OUTPUT OF INCREASE BENDING DEVICE
IB
a
b
c
d
TIME
a
b
c
d
TIME
DB
DS
OUTPUT OF DECREASE BENDING DEVICE
WORK ROLL BENDING FORCE (COMPOSITE FORCE)
FB
a
b
c
d
TIME
FR

Fig.10

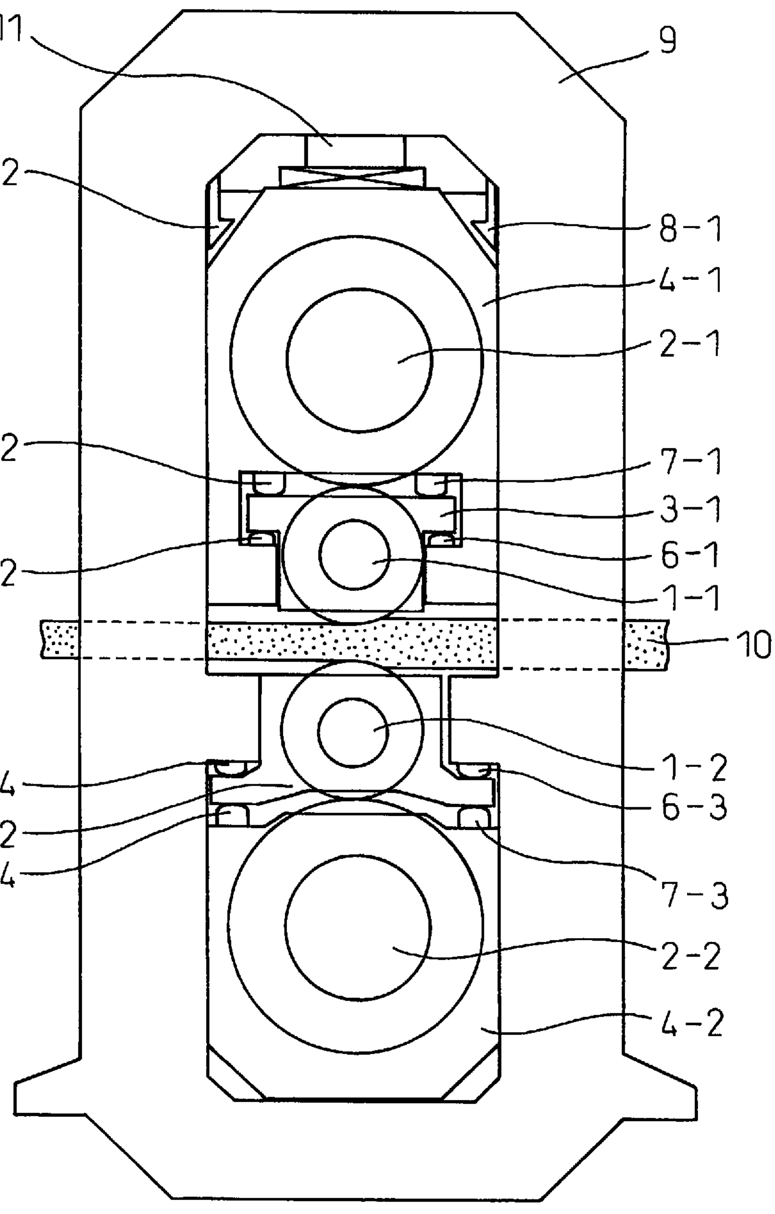


Fig.11

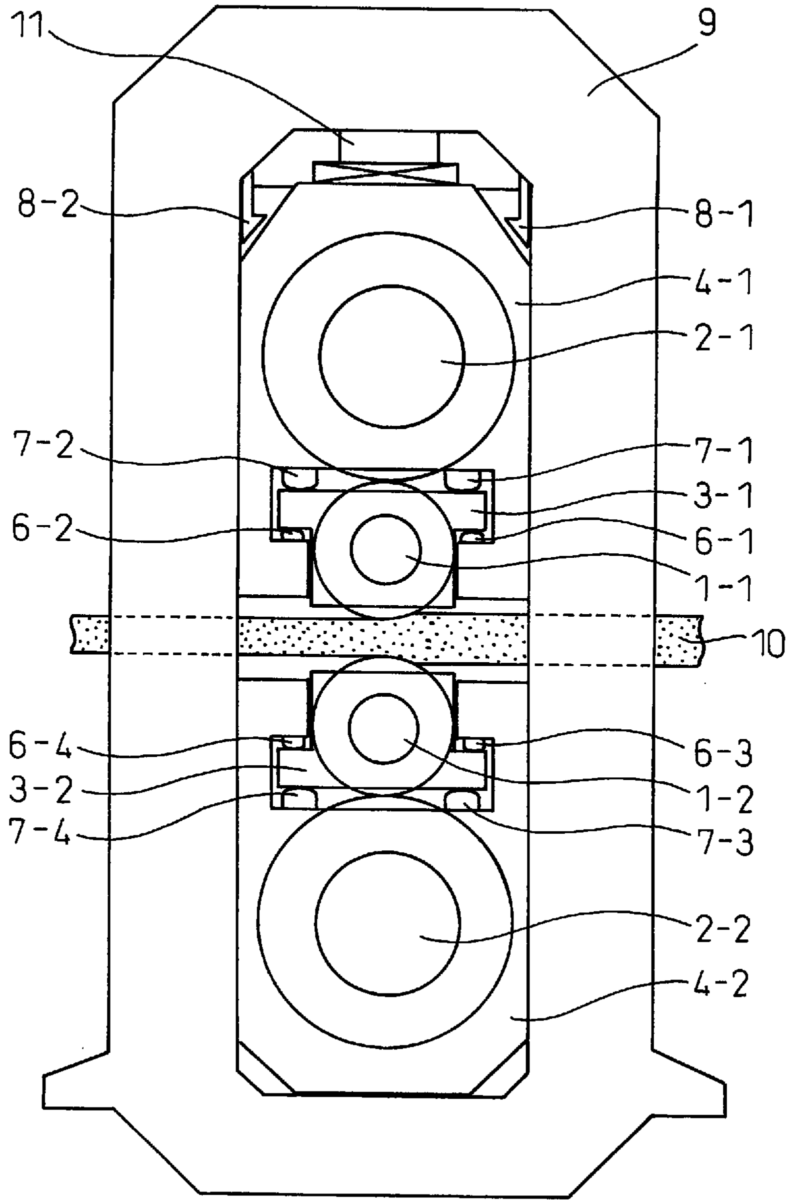


Fig. 12

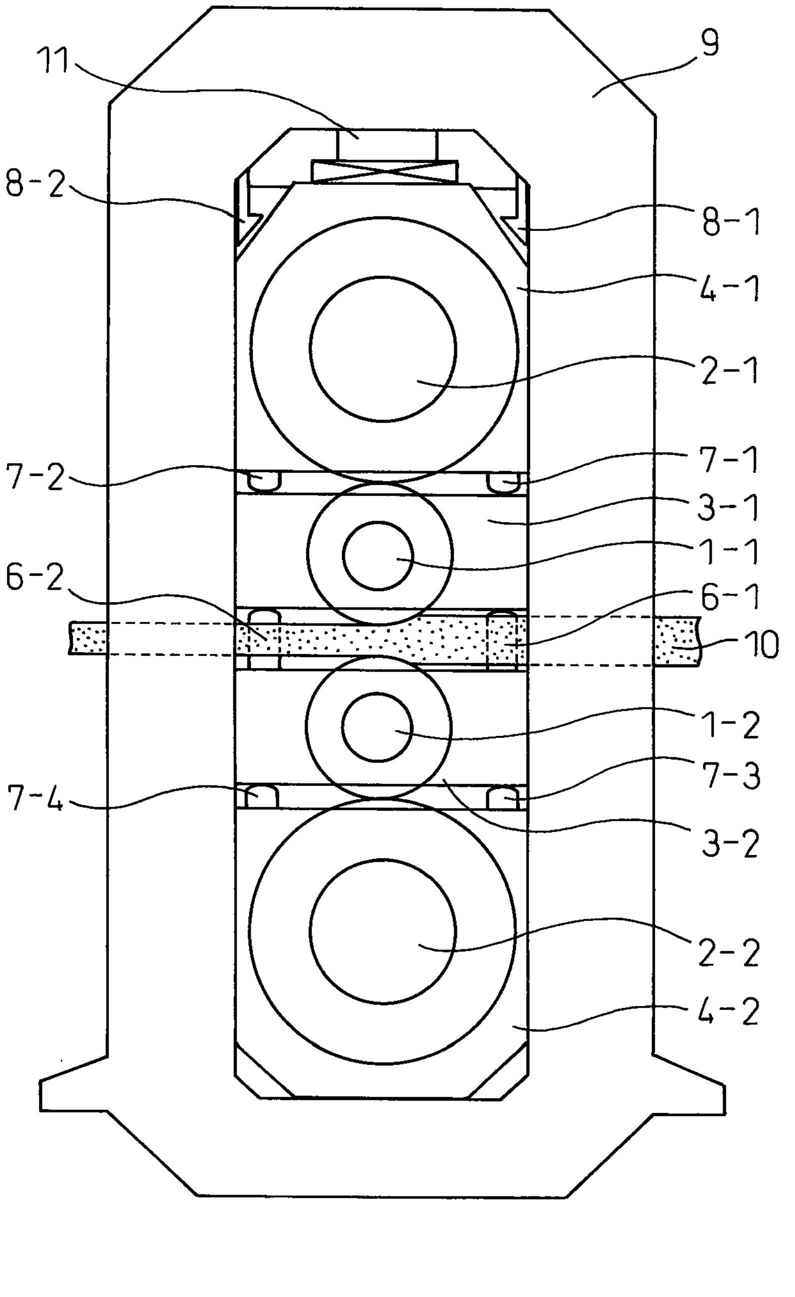


Fig.13

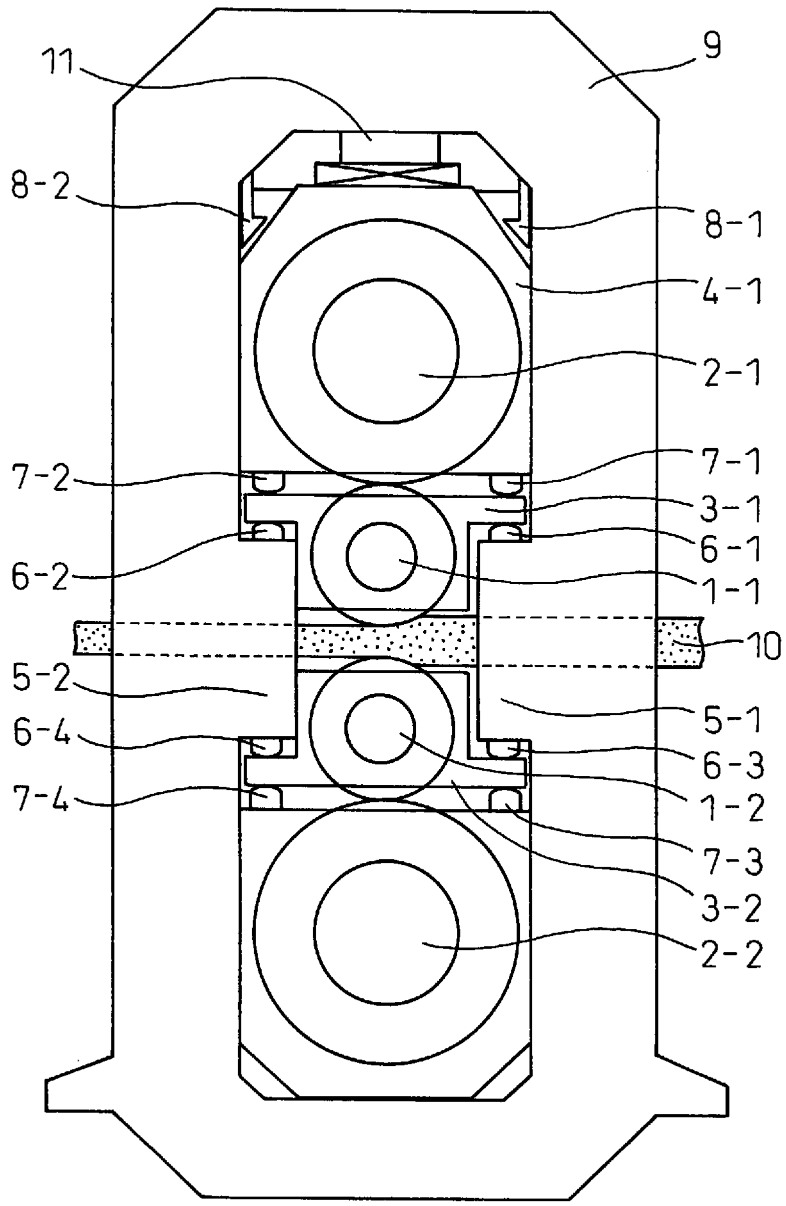
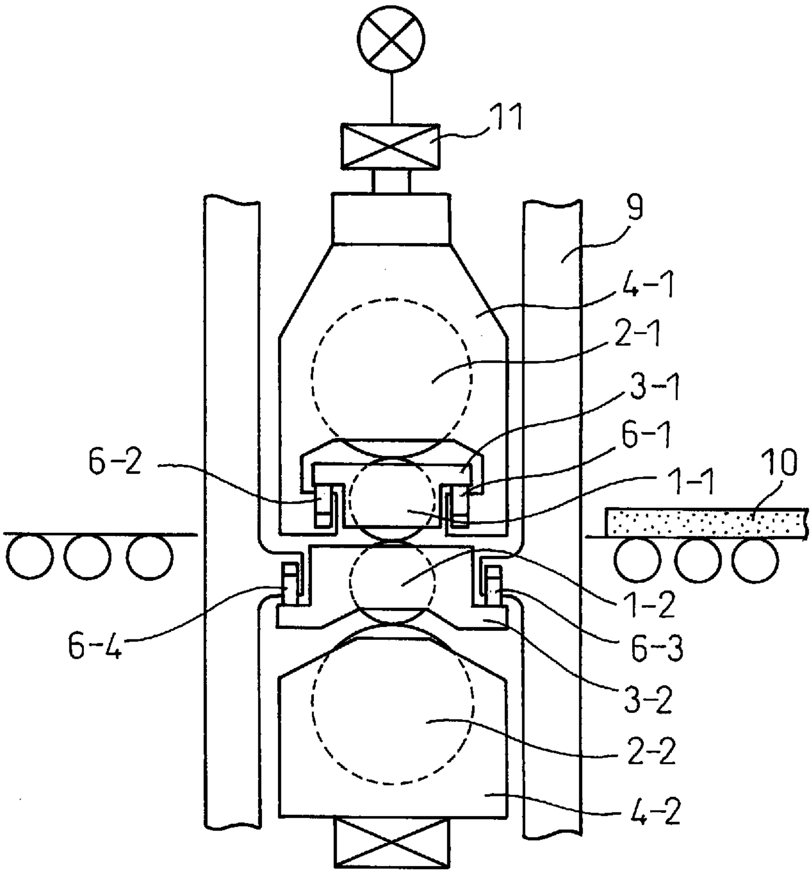


Fig.14



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2011/050784

A. CLASSIFICATION OF SUBJECT MATTER
B21B13/14(2006.01)i, *B21B29/00*(2006.01)i, *B21B37/38*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21B13/14, B21B29/00, B21B37/38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 27384/1986(Laid-open No. 142403/1987) (Hitachi, Ltd.), 08 September 1987 (08.09.1987), drawings (Family: none)	1-6
A	JP 2-280910 A (Kawasaki Steel Corp.), 16 November 1990 (16.11.1990), drawings (Family: none)	1-6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 February, 2011 (09.02.11)	22 February, 2011 (22.02.11)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/050784

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 59-42106 A (Hitachi, Ltd.), 08 March 1984 (08.03.1984), drawings (Family: none)	1-6
A	JP 8-215730 A (Nippon Steel Corp.), 27 August 1996 (27.08.1996), fig. 2 to 5 (Family: none)	1-6
A	JP 63-199006 A (Nippon Steel Corp.), 17 August 1988 (17.08.1988), fig. 2 (Family: none)	1-6
A	JP 11-267728 A (Kawasaki Steel Corp.), 05 October 1999 (05.10.1999), fig. 2, 4 (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6087011 A **[0009]**
- JP 62220205 A **[0009]**
- JP 6198307 A **[0009]**
- JP 4052014 A **[0009]**