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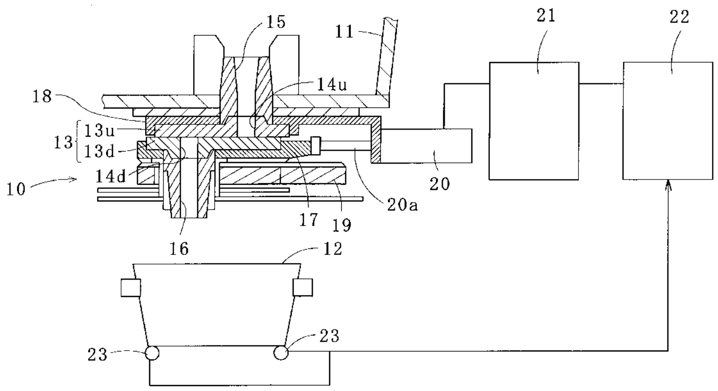
(54) **METHOD OF CONTROLLING SLIDING NOZZLE DEVICE AND PLATE USED THEREFOR**

(57) A method of controlling a sliding nozzle device 10 and a plate 13 used therefor, even if operational conditions are changed, automatically optimizing sliding conditions of the device 10, increasing a life of the plate 13, and reducing a corrosion rate and a stroke length of the plate 13. When the device 10 is controlled, if an average cumulative sliding rate of the plate 13 is outside a control range, a sliding rate of the plate 13 is changed within a preset range, thereby automatically optimizing the sliding conditions of the device 10 even with an operational condition change. Also, 3% to 20% of average sliding rate can reduce the corrosion rate of the plate 13 and drastically increase the life of the plate 13.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a method of controlling a sliding nozzle device placed at a bottom of a ladle, which is used in continuous casting facilities, and also relates to plates used for the sliding nozzle device.

BACKGROUND ART

[0002] Amolten steel flow discharged from a ladle to a tundish is controlled by a sliding nozzle device. The sliding nozzle device uses a plurality of sliding nozzle plates (hereinafter, "sliding nozzle plates" are simply referred to as "plates"), each having a nozzle bore and made of a refractory material. While the plurality of plates are pressed with a high pressure, at least one of the plates is slid for adjusting an opening ratio of the nozzle bore, thereby controlling the molten steel flow.

[0003] One of the known methods of controlling the sliding nozzle device includes measuring a weight of molten steel in the tundish, and adjusting an opening ratio of the nozzle bore based on (a) a deviation between a measured value and a reference value of the molten steel weight, or (b) a change rate of the molten steel weight. For adjusting the opening ratio of the nozzle bore, for example, two types of sliding distances (control parameters) of the plate, such as long and short, are set in advance, and these two types of output signals are transmitted from a control device as pulse signals according to a deviation level. An output cycle of the pulse signals is also controlled according to a preset value (control parameter), for example, 5 seconds.

[0004] When the opening ratio of the nozzle bore is controlled by the above-described method, the plate may be slid frequently to maintain molten steel at a constant level, regardless of operational conditions. For this reason, corrosion of the plates is accelerated, thereby severely limiting the number of use of the plates.

[0005] Consequently, Patent Documents 1 and 2 disclose methods of controlling a sliding nozzle device, in which a position of a plate is maintained in the case that a direction of a change in the measured value is approaching to the reference value, even if a weight of molten steel in a tundish has a deviation between a measured value and a reference value thereof. With this method, the life of the plates can be increased, and further a stability of the weight of molten steel in the tundish can be improved. Therefore, it is considered that fluctuations in the weight or a surface level of molten steel due to disturbances can be further reduced.

Patent Document 3 discloses a method of controlling a sliding nozzle device by adjusting an opening ratio of a nozzle bore, based on a relation among a molten steel head in a ladle, the opening ratio of the nozzle bore, and molten steel flow discharged from the ladle.

[0006] Recently, in accordance with requests to reduce costs and operator's burden of handling, there is a growing need for downsizing the plate. For example, Patent Document 4 describes that by defining a distance from an edge of a nozzle bore of a plate to an end of the plate, the plate can be economically shaped, but does not cause a leakage of molten steel.

[Patent Document 1] Japanese Unexamined Patent Application Publication No. 62-158556
[Patent Document 2] Japanese Unexamined Patent Application Publication No. 62-158557
[Patent Document 3] Japanese Unexamined Patent Application Publication No. 2003-164951
[Patent Document 4] Japanese Unexamined Patent Application Publication No. 11-138243

DISCLOSURE OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0007] If a steel grade is changed in casting operation, constituents of molten steel are changed. Accordingly, the nozzle bore may tend to be clogged, or on the contrary, corrosion of the nozzle bore may be accelerated, which may change an amount of molten steel discharged from the plate. Additionally, if a bore diameter of the nozzle is changed, the amount of molten steel discharged from the plate is changed. Specifically, if an inclusion attaches to the nozzle bore and a cross-sectional area of the nozzle bore decreases, an initially-set sliding distance makes only a small change in molten steel flow, which may require two or three continuous slides of the plate in the direction where the area of the nozzle bore increases. As a result, the number of slides becomes excessive. On the other hand, if the bore diameter of the nozzle increases, one slide of the plate opens the nozzle bore too large, which requires the plate to be slid in the opposite direction shortly. This also results in an increase of the number of slides.

[0008] However, since control parameters are fixed, the methods disclosed in Patent Documents 1 and 2 are not adaptable to the variation in molten steel flow caused by some changes in the steel grade, the bore diameter of the nozzle, and so on. Thus, this method may not well control the weight of molten steel in the tundish. What is worse, corrosion of the plates increases with a rise in frequency of slides of the plate, which may shorten the life of the plates. In this case, a troublesome re-tuning has to be performed for a control system of the sliding nozzle device.

[0009] If a drive mechanism of the sliding nozzle device is changed from a link drive system, linking a slide frame and a hydraulic cylinder via an arm, to a direct drive system, directly coupling the slide frame and the hydraulic cylinder, an amount of backlash in a linkage is decreased, so that the plate moves too much compared to before. Accordingly, corrosion of the plate increases with the rise in frequency of slides of the plate, which may shorten the life of the plate.

[0010] On the other hand, in the method described in Patent Document 3, if the sliding distance of the plate is long, corrosion of the plate increases, which may increase a frequency in opening and closing the nozzle bore. This causes a problem that the number of use of the plates is limited severely.

[0011] In general, corrosion of the plates is broadly classified into edge corrosion Q (see FIG. 10 (a)), in which an edge of the nozzle bore is corroded at reducing the molten steel flow, and stroke corrosion R (see FIG. 10 (b)), in which a sliding surface of the plate is corroded due to sliding movements of the plate. As the number of slides or the sliding distance of the plate is increased, these two types of corrosion are accelerated.

Such an increase of corrosion of the plates may cause leakage of molten steel, so that the stroke length of the plate has to be twice or more the bore diameter of the nozzle, as disclosed in Patent Document 4. Therefore, the conventional method has a limitation on reducing a total length of the plate.

[0012] The present invention has been made in view of the above circumstances and aims to provide a method of controlling a sliding nozzle device and plates used therefor, which are operable to automatically optimize sliding conditions of the sliding nozzle device and to increase life of the plates, even when operational conditions are changed.

The present invention also aims to provide a method of controlling a sliding nozzle device and plates used therefor, which are operable to decrease a corrosion rate of the plates and the stroke length of the plate.

MEANS FOR SOLVING THE PROBLEMS

[0013] A first aspect of the present invention provides a method of controlling a sliding nozzle device in order to control a flow of molten steel discharged from a ladle to a tundish in continuous casting, the method comprising: measuring a weight of molten steel in the tundish; calculating a deviation between the measured value and a reference value of the weight of molten steel; and outputting control signals at a predetermined cycle, the control signals controlling a sliding distance of a plate, based on the deviation and/or a change rate in the weight of molten steel in the tundish; the method **characterized in that** an average cumulative sliding rate (%/minute) of the plate is calculated; and if the average cumulative sliding rate (%/minute) of the plate is out of a preset control range, a sliding rate of the plate is changed within a predetermined setting range.

The term "sliding rate (%) " as used herein refers to a value calculated by dividing a single sliding distance of the plate for controlling the molten steel flow by the bore diameter of the nozzle provided in the plate before use. This is because the molten steel flow per unit time varies with the bore diameters of the nozzle, and accordingly the sliding distance of the plate varies with the bore diameters of the nozzle, when the molten steel flow is controlled by the sliding nozzle device. Also, the term "average cumulative sliding rate of the plate" as used herein refers to an average value of a cumulative sliding rate of the plate per predetermined time, where the cumulative sliding rate of the plate is a product of the sliding rate and the number of slides.

[0014] The inventors of the present invention found out the following: in the sliding nozzle device control, the cumulative sliding rate of the plate, namely, the product of the sliding rate and the number of slides, greatly affected the life of the plates; and it was possible to automatically optimize the sliding conditions of the device by controlling this cumulative sliding rate within an optimal range, even when the operational conditions were changed. The first aspect of the present invention is based on the above knowledge.

[0015] In the method of controlling the sliding nozzle device according to the first aspect of the present invention, it is preferable that the control range for the average cumulative sliding rate of the plate is between 0. 5 %/minute and 18 %/minute.

If the average cumulative sliding rate is less than 0.5 %/minute, a control accuracy of the weight of molten steel in the tundish is reduced. If the average cumulative sliding rate exceeds 18 %/minute, the life of the plates is reduced.

[0016] In the method of controlling the sliding nozzle device according to the first aspect of the present invention, it is also preferable that the predetermined setting range for the sliding rate of the plate is between 3 % and 20 %.

If the sliding rate of the plate is less than 3 %, the control accuracy of the weight of molten steel in the tundish is reduced. If the sliding rate of the plate exceeds 20 %, the life of the plates is reduced.

[0017] A second aspect of the present invention provides a method of controlling a sliding nozzle device used with a ladle, **characterized in that** an average sliding rate of a plate included in the sliding nozzle device is between 3 % and 20 %.

The term "average sliding rate (%)" as used herein refers to an average value of the sliding rate for 60 minutes. Specifically, the average sliding rate can be expressed in the following formula: an average sliding rate (%) = 100[(a total sliding distance of a plate for 60 minutes/the number of slides for 60 minutes) /a bore diameter of a nozzle provided in the plate before use.]

[0018] As previously explained, when controlling the molten steel flow by the sliding nozzle device, the molten steel flow per unit time varies with the bore diameters of the nozzle, and accordingly the sliding distance of the plate varies with the bore diameters of the nozzle. For this reason, the average value of the sliding rate for 60 minutes is used as the control parameter, and the value of the control parameter is defined.

[0019] The average sliding rate is between 3% and 20%, more preferably between 5% and 15%. If the average sliding rate exceeds 20%, the stroke corrosion is increased and the life of the plates is reduced. Moreover, the number of slides is increased, and thus the stroke corrosion is increased and the life of the plates is reduced. If the average sliding rate is less than 3%, the weight of molten steel in the tundish fluctuates widely, which deteriorates flow controllability.

[0020] In the second aspect of the present invention, the average sliding rate is set between 3% and 20%, and the sliding distance of the plate is reduced to a minimal required, thereby reducing the corrosion rate of the plates. In addition, the number of slides can be reduced with a reduction of the average sliding rate, thereby further reducing the corrosion rate of the plates.

[0021] In the method of controlling the sliding nozzle device according to the second aspect of the present invention, it is preferable that the number of slides of the plate is between 10 times and 60 times per 60 minutes.

The second aspect of the present invention aims to minimize a sliding amount of the plate and thereby to reduce the corrosion rate of the plates, by setting the number of slides of the plate per 60 minutes between 10 times and 60 times, more preferably between 10 times and 30 times. If the number of slides of the plate for 60 minutes exceeds 60 times, the corrosion rate of the plates is increased and the life of the plates is reduced. On the other hand, if the number of slides of the plate for 60 minutes is less than 10 times, the weight of molten steel in the tundish fluctuates widely, which deteriorates flow controllability.

[0022] In the methods of controlling the sliding nozzle device according to the first and second aspects of the present invention, it is preferable that a stroke length of the plate is 1.5 times or more but less than 2 times a bore diameter of the nozzle provided in the plate.

If the stroke length of the plate is less than 1.5 times the bore diameter of the nozzle, the plate may not have an enough corrosion allowance, thereby reducing the life of the plates. On the other hand, if the stroke length is twice or more the bore diameter of the nozzle, the life of the plates has almost no difference, but the total length of the plate is increased.

[0023] The term "stroke length of the plate" as used herein refers to a distance between the center of the nozzle bore of the plate and a theoretical point that is a center of a nozzle bore of a counterpart plate theoretically projected on the plate, at a position where a distance between the center of the nozzle bore of the plate and the center of the nozzle bore of the counterpart plate contacting with the plate is the longest, in the sliding nozzle device for which the plate is used.

In FIG. 2, the plate is positioned such that the distance between the nozzle bores is the longest, in the sliding nozzle device using the plate. Also in the figure, the stroke length of an upper plate is a distance S between a center A of the nozzle bore of the upper plate and a theoretical point B of the upper plate, in which the theoretical point B corresponds to the center of the nozzle bore of a lower plate.

[0024] In the methods of controlling the sliding nozzle device according to the first and second aspects of the present invention, it is also preferable that a plate used in the methods has the stroke length of 1.5 times or more but less than 2 times the bore diameter of the nozzle.

EFFECT OF THE INVENTION

[0025] In the method of controlling the sliding nozzle device according to the present invention, when the average cumulative sliding rate of the plate is out of the control range, the sliding conditions of the sliding nozzle device can be optimized automatically by changing the sliding rate of the plate within the predetermined setting range, even if the operational conditions are changed. As a result, the corrosion rate of the plates is reduced, thereby improving a tolerance of the plates, and further downsizing the plates.

[0026] Also in the method of controlling the sliding nozzle device according to the present invention, by setting the average sliding rate between 3% and 20%, the corrosion rate of the plates is reduced, and the life of the plates is drastically improved. Moreover, in the method of controlling the sliding nozzle device and the plates used therefor according to the present invention, the stroke length of the plate is set 1.5 to 2 times the bore diameter of the nozzle, so that the plates can be downsized.

BRIEF DESCRIPTION OF DRAWINGS

[0027]

FIG. 1 is a schematic view showing a configuration of a sliding nozzle device, using control methods according to first and second embodiments of the present invention.
FIG. 2 is a sectional side view showing plates of the sliding nozzle device.
FIG. 3 is a control flowchart showing the method of controlling the sliding nozzle device according to the first embodiment of the present invention.
FIG. 4 is an explanatory diagram showing a time history in a deviation between a weight of molten steel in a tundish and a reference value thereof.
FIG. 5 is a graph showing a relation between a life of a plate and an average cumulative sliding rate of the plate.
FIG. 6 is a graph showing a relation between a life of a plate and an average sliding rate of the plate.
FIG. 7 is a graph showing a relation between a life of a plate and a stroke length divided by a bore diameter of a nozzle.
FIG. 8 is a graph showing a relation between a life of a plate and an average sliding rate.
FIG. 9 is a graph showing a relation between a life of a plate and a stroke length divided by a bore diameter of a nozzle.
FIG. 10(a) is a sectional side view of plates showing edge corrosion of the plates.
FIG. 10(b) is a sectional side view of plates showing stroke corrosion of the plates.

DESCRIPTION OF REFERENCE NUMERALS

[0028] 10: sliding nozzle device; 11: ladle; 12: tundish; 13: plate (sliding nozzle plates) ; 13u: upper plate; 13d: lower plate; 14u, 14d: nozzle bore; 15: upper nozzle; 16: lower nozzle; 17: slide frame; 18: upside frame; 19: suspending frame; 20: hydraulic cylinder; 20a: rod; 21: hydraulic unit; 22: control device; 23: load cell

BEST MODE FOR CARRYING OUT THE INVENTION

[0029] Embodiments of the present invention will be described referring to the accompanying drawings for a better understanding of the present invention. Hereinafter, a description will be given on sliding nozzle plates including two plates: an upper plate (fixed plate) and a lower plate (sliding plate) . Basically the same description can be also applied to the sliding nozzle plates including three plates: an upper plate (upper fixed plate), a middle plate (sliding plate), and a lower plate (lower fixed plate).

[Configuration of a sliding nozzle device]

[0030] FIG. 1 shows a configuration of a sliding nozzle device 10, using control methods according to first and second embodiments of the present invention.
The sliding nozzle device 10 comprises a plate 13 (sliding nozzle plates) and a sliding means for sliding the plate 13.
[0031] The plate 13 includes an upper plate 13u and a lower plate 13d having a nozzle bore 14u and a nozzle bore 14d, respectively. The upper plate 13u is fixed at a bottom of a ladle 11 via an upside frame 18, and an upper nozzle 15 is connected to the nozzle bore 14u. On the other hand, the lower plate 13d is fixed on a slide frame 17 located inside of a suspending frame 19, which is openable and closable with respect to the upside frame 18. And, the lower plate 13d slides along a lower surface of the upper plate 13u. In addition, a lower nozzle 16 is connected to the nozzle bore 14d of the lower plate 13d.
[0032] The upside frame 18 extends in a sliding direction of the slide frame 17. At one end of the upside frame 18 in the extending direction thereof, a hydraulic cylinder 20 is placed. And, an end portion of a rod 20a of the hydraulic cylinder 20 is connected to one end of the slide frame 17.
[0033] A tundish 12 is placed immediately beneath the ladle 11. At the bottom of the tundish 12, load cells 23, 23 are provided for measuring a weight of molten steel in the tundish 12. Outputs from the load cells 23, 23 are input to a control device 22. The control device 22 outputs control signals, corresponding to the output values from the load cells 23, 23, to a hydraulic unit 21. The hydraulic unit 21 activates the hydraulic cylinder 20 according to the control signals, and slides the slide frame 17.
[0034] [Method of controlling the sliding nozzle device according to a first embodiment of the present invention]
Referring to a control flow chart in FIG. 3, a description will be given on a method of controlling the sliding nozzle device according to the first embodiment of the present invention.
[0035] (1) The control device 22 receives the output signals transmitted from the load cells 23, 23, which are placed at the bottom of the tundish 12 (S1).
(2) The control device 22 performs a conventional automatic control of the sliding nozzle device, in which a control force of the hydraulic cylinder 20 is calculated based on a deviation between the output signals from the load cells 23, 23 and the reference value thereof. Then, the control device 22 outputs the control signals to the hydraulic unit 21, and the hydraulic unit 21 drives the hydraulic cylinder 20 based on the control signals and slides the lower plate 13d, thereby controlling the opening ratio of the nozzle bore (S2). The opening ratio is controlled in the same method as disclosed in

Patent Document 1 and so on. That is to say, predetermined ranges are set between the reference values and change rates of the molten steel weight as shown in Table 1, and types of the control signals are determined within each reference setting. Also, an output cycle of the control signals is set at 5 seconds.

[0036]

[Table 1]

Control Reference for Molten Steel Weight		K≦-A	-A<K≦0	0<K≦+A	+A<K
+W3	1.0 to 3.0%	Stay	Close small	Close large	Close large
+W2	0.5 to 1.0%	Stay	Stay	Close small	Close large
+W1	0 to 0.5%	Stay	Stay	Stay	Close small
-W1	-0.5 to 0%	Open small	Stay	Stay	Stay
-W2	-1.0 to -0.5%	Open large	Open small	Stay	Stay
-W3	-3.0 to -1.0%	Open large	Open large	Open small	Stay

[0037] In Table 1, "K" represents the change rate in the weight of molten steel (kg/5 sec.), and "A" represents a constant. "Close small" indicates a pulse signal for sliding a sliding plate for a short distance, in a direction where an opening area of a nozzle bore becomes small. "Close large" indicates a pulse signal for sliding a sliding plate for a long distance, in a direction where an opening area of a nozzle bore becomes small. "Open small" indicates a pulse signal for sliding the sliding plate for a short distance, in a direction where the opening area of the nozzle bore becomes large. "Open large" indicates a pulse signal for sliding the sliding plate for a long distance, in a direction where the opening area of the nozzle bore becomes large. In this instance, provided that the sliding distances of the plate are 5 mm and 10 mm and the bore diameter of the nozzle is 85 mm, then the sliding rate in "Close small" and "Open small" is each 6%, and the sliding rate in "Close large" and "Open large" is each 12%. In a state of "Stay," the sliding plate does not slide.

[0038] (3) After outputting the control signals in Table 1, to obtain an optimal control, the control device 22 adjusts the control parameter related to the sliding distance of the plate in the following procedures.

First, an average cumulative sliding rate (%/minute) of the plate is calculated (S3).

[0039] The average cumulative sliding rate (%/minute) of the plate is calculated based on a cumulative sliding rate (%) of the plate and the number of slides (number of times) of the plate within a predeterminedperiod. In this embodiment, the cumulative sliding rate (%) of the plate is calculated based on the types of the control signals and the number of outgoing control signals for sliding the plate, both of which are initially set. For example, in Table 1, if "Open large (12%)" is transmitted twice, "Close large (12%)" is transmitted once, "Close small (6%)" is transmitted once, and "Stay" is transmitted twice for last ten minutes, then the cumulative sliding rate for ten minutes is 42%. And, the number of the outgoing control signals for sliding the plate in this period is four times, so that the average cumulative sliding rate of the plate for ten minutes is 10.5%/minute.

[0040] As for the control signals for sliding the plate, the sliding rates of the plate can be calculated by taking an actual measurement on each control signal (pulse signal) and the sliding distance of the plate under the condition that the plate is before use and pressure is put on a surface of the plate. Alternatively, a position sensor may be provided in a drive device such as the hydraulic cylinder, and measured results thereof may be used as the sliding distance of the plate. Further alternatively, an actual sliding distance of the plate may be measured.

[0041] A calculation of this average cumulative sliding rate (%/minute) of the plate begins at least 5 minutes or more prior to the starting time of the calculation (the time of the control signal output) . If less than 5 minutes, an accuracy of the average cumulative sliding rate (%/minute) is decreased. There is no particular upper limit on the period for calculating the average cumulative sliding rate (%/minute), so that the calculation period can be a cumulative time from the start to the end of casting in the ladle, for example. In this case, the sliding distance and the number of slides of the plate due to the control signals are continuously counted since the control starts right after a beginning of casting, and then, in every output cycle (e.g., 5 seconds) of the control signals, the average cumulative sliding rate is calculated based on data that has been accumulated since the beginning of casting. In addition, an arbitrary specified period, namely, 5 minutes to 60 minutes prior to the time of the control signal output, may be determined as the calculation period.

[0042] (4) The average cumulative sliding rate of the plate is examined whether or not it is within a control range between 0.5%/minute and 18%/minute (S4).

(5) When the average cumulative sliding rate is less than 0.5%/minute, the control parameter related to the sliding distance of the plate is changed to increase the sliding distance of the plate. When the average cumulative sliding rate exceeds 18%/minute, the control parameter related to the sliding distance of the plate is changed to decrease the sliding distance of the plate (S6). When the average cumulative sliding rate is less than 0.5%/minute, the control accuracy of

the weight of molten steel in the tundish is reduced, and when the average cumulative sliding rate exceeds 18%/minute, the life of the plates is reduced.

[0043] In this regard, it is more preferable to set the sliding rate of the plate in the range between 3% and 20%. If the sliding rate of the plate is less than 3%, the control accuracy of the weight of molten steel in the tundish is reduced, and if the sliding rate of the plate exceeds 20%, the life of the plates is reduced. As for a setting of the sliding rate of the plate, if a plurality of the control signals is used, an average value thereof can be set as the sliding rate of the plate. For example, in Table 1, the sliding rates of the plate are 6% and 12% as the control signals. In this case, the average sliding rate is 9%.

[0044] As for a sliding speed of the plate or the output cycle of the control signals, in addition to the sliding rate of the plate, the predetermined control range is set and the control is performed with variable control parameters, which can further improve the accuracy of the control method of this embodiment.

[0045] (6) If the average cumulative sliding rate of the plate is within the control range, it is examined whether or not a casting operation is completed (S5).

(7) If the casting operation is not completed yet, the above-described procedure (1) and subsequent procedures are performed again from the step S1. On the other hand, if the casting operation is completed, the sliding nozzle device 10 is stopped.

[0046] In the control method of this embodiment, in addition to the average cumulative sliding rate (%/minute) of the plate, a cycle (minute) of the weight of molten steel in the tundish and/or the number of inflection points (number/minute) in the weight of molten steel in the tundish are controlled, which can improve the accuracy of the flow control.

[0047] FIG. 4 shows a time history in the deviation between the weight of molten steel in the tundish and the reference value thereof. FIG. 4 shows results of the control performed by the control method shown in the flow of FIG. 3, using the sliding nozzle device of FIG. 1. Before this control method was used, the average cumulative sliding rate (%/minute) of the plate was 20%/minute, which was out of the range set in this embodiment. However, by changing the control parameter related to the sliding distance of the plate, namely, by changing the sliding rates of the plate into 12% and 6% (see Table 1), the average cumulative sliding rate of the plate became 9%/minute. In other words, the sliding distance of the lower plate was decreased, and what was more, the number of slides of the plate was reduced, and the life of the plates was increased. Also, in FIG. 4, a fluctuation cycle of a weight deviation was extended after the control turned on.

[0048] FIG. 5 shows a relation between the life of the plates and the average cumulative sliding rate of the plate. If the average cumulative sliding rate of the plate is 18%/minute or less, the life of the plates is increased. Moreover, if the average cumulative sliding rate is 12%/minute or less, the life of the plates is further increased. If the average cumulative sliding rate exceeds 18%/minute, the edge corrosion and the stroke corrosion of the plate are increased, thereby reducing the life of the plates.

[0049] FIG. 6 shows a relation between the life of the plates and the average sliding rate of the plate. Tests were conducted under the condition that the average cumulative sliding rate of the plate was 18% or less. If the average sliding rate of the plate is 20% or less, the life of the plates is increased. Moreover, if the average sliding rate is 10% or less, the life of the plates is further increased. If the average sliding rate exceeds 20%, the edge corrosion and the stroke corrosion of the plates are increased, thereby reducing the life of the plates.

[0050] FIG. 7 shows a relation between the life of the plates and the stroke length divided by the bore diameter of the nozzle. The tests of FIG.7 were performed by the control method shown in FIGS. 1 and 3, but only the stroke length of the plate was changed due to a setting change of the sliding nozzle device. The tests were conducted using three pieces of the plates with respect to each stroke length, and the test results were evaluated on an average value of the life of the plates. The test results showed that the life of the plates was rapidly reduced if the stroke length was less than 1.5 times the bore diameter of the nozzle, but the life of the plates had no significant change even if the stroke length was 2 times or more the bore diameter of the nozzle.

[0051] The tests of FIGS. 5 to 7 were performed using the plate having a length of 600 mm, a width of 260 mm, a thickness of 50 mm, and a nozzle bore diameter of 85 mm. The plate was made of tar-impregnated alumina-carbon material with 80% or more of Al_2O_3. At the tests, pressure acting on the surface of the plate was 100 kN, a casting period was 45 to 55 minutes per one heat, and a ladle capacity was 300 ton.

[0052] The number of slides and the sliding distance (mm) were measured by an operator at the side of the sliding nozzle device. The average sliding rate was calculated in the following formula: an average sliding rate (%) = 100[(a total sliding distance of a plate for 60 minutes/the number of slides for 60 minutes) /a bore diameter of a nozzle provided in the plate before use.] In addition, the sliding distance and the number of slides were measured for 60 minutes in the same ladle. For example, when one heat for a certain ladle was completed in 45 minutes, a further 15-minute heat for the same ladle was taken into account in order to measure the sliding distance and the number of slides for 60 minutes in total. Here, the sliding distance and the number of slides excluded the following: slides of the plate for setting a predetermined opening ratio of the nozzle bore provided in the plate, at the start of the slide; and slides of the plate for stopping a discharge of molten steel, at the end of casting and in an emergency. Also, the tests of FIGS. 5 and 6 were performed by changing the sliding speed of the plate, the sliding distance of the plate, a range of a dead zone that keeps the position of the plate, the output cycle, and so on.

[Method of controlling a sliding nozzle device according to a second embodiment of the present invention]

[0053] Descriptions will be given on a method of controlling a sliding nozzle device according to a second embodiment of the present invention.

[0054] Provided that an internal diameter of nozzle bores 14u, 14d is "D," a sliding distance of the plate 13 is 0.2D if an average sliding rate of the plate 13 is 20%, whereas the sliding distance of the plate 13 is 0.03D if the average sliding rate of the plate 13 is 3%. A lower plate 13d is controlled by pulses output from the control device 22. Thus, when the lower plate 13d is controlled by two types of pulses, namely, large pulses and small pulses, the average sliding rate of the plate 13 becomes between 3% and 20% theoretically if the sliding distance controlled by the large pulses is set at 0.2D or less, and the sliding distance controlled by the small pulses is set at 0.3D or more. The same can be applied to the case of using a plurality of pulses. In other words, it is only necessary to set the sliding distance controlled by a maximum pulse at 0.2D or less, and the sliding distance controlled by a minimum pulse at 0. 03D or more.

[0055] Next, a description will be given on results of a control test for a sliding nozzle device 10, using the average sliding rate as a parameter.

[0056] FIG. 8 is a graph showing a relation between a life of the plates and the average sliding rate. The life of the plates in a vertical axis of the graph indicates the number of heats where the plates were usable. An operator visually observed the edge corrosion and the stroke corrosion at the surface of the plate used, and examined whether or not the plate could be used again.

[0057] The tests were conducted using the plate having a length of 600 mm, a width of 260 mm, a thickness of 50 mm, and a nozzle bore diameter of 85 mm. The plate was made of tar-impregnated alumina-carbon material with 80% or more of Al_2O_3. In addition, a means for sliding the plate in the sliding nozzle device 10 had a stroke of 160 mm, and the plate 13 had a stroke length S of 160 mm (see FIG. 2). At the tests, the pressure acting on the surface of the plate was 100 kN, a casting period was 45 to 55 minutes per one heat, and a ladle capacity was 300 ton.

[0058] In the tests, using the method of controlling the sliding nozzle device disclosed in Japanese Unexamined Patent Application Publication No. 62-158556 (JP 62-158556), the number of slides of the plate 13 was also controlled.
According to the method of controlling the sliding nozzle device disclosed in JP 62-158556, a position of the plate is maintained (a) when a measured value according to load cells 23, 23 is within a dead zone close to a reference value, or (b) when the measured value is out of the dead zone, but a deviation between the measured value and the reference value is within a predetermined range and the measured value is approaching to the reference value.

[0059] In this test, the number of slides of the plate was controlled by adjusting a setting of the sliding speed of the plate, a setting of the sliding distance of the plate, and a range of the dead zone where the position of the plate was maintained. However, a control range of a weight of molten steel in a tundish was within ±1 percent by mass.

[0060] As for the sliding distance of the plate, two types of long and short travel distances were set. In the case that the plate slid in the same direction twice or more, the number of slides was counted as twice or more. The sliding distance was set based on a period and an oil quantity for exciting an electromagnetic valve in a hydraulic system.

[0061] The number of slides and the sliding distance (mm) were measured under the same conditions as the above-described method of controlling the sliding nozzle device according to the first embodiment of the present invention, and the average sliding rate was calculated in the above-described formula.

[0062] In FIG. 8, the number of slides is divided into groups per 10 slides, and the life of the plates of each group is plotted on the average sliding rates. According to FIG. 8, it is obvious that the life of the plates is increased as the average sliding rate is decreased. Specifically, the life of the plates is drastically increased as the average sliding rate becomes 20% or less, whereas the life of the plates is extremely decreased as the average sliding rate exceeds 20%. In addition, the life of the plates becomes longer with lesser number of slides. Especially, the life of the plates became the longest when the number of slides was 10 to 30 times. When the number of slides exceeded 60 times, the life of the plates became 7 times or less even if the average sliding rate was reduced.
In addition, when the average sliding rate was less than 3 % or when the number of slides was less than 10 times, the control range of the weight of molten steel in the tundish exceeded ±3%, and the flow controllability was slightly decreased.

[0063] FIG. 9 shows a relation between the life of the plates and the stroke length divided by the bore diameter of the nozzle. As for the plate, the plate used in FIG. 8 was also used, but only the stroke length was changed due to a setting change of the sliding nozzle device. Test results were obtained under the same test conditions as the above-described method in FIG. 8, except for the conditions that the number of slides was within 21 to 30 times and the average sliding rate was within 10 to 15%. The test was conducted using three pieces of the plates with respect to each stroke length, and the test results were evaluated on an average value of the life of the plates.
The test results showed that the life of the plates was rapidly reduced if the stroke length was less than 1.5 times the bore diameter of the nozzle, but the life of the plates had no significant change even if the stroke length was 2 times or more the bore diameter of the nozzle.

[0064] A level fluctuation of molten steel in a mold adversely affects steel quality, so that a molten steel flow from a tundish to the mold is controlled with a high accuracy. Consequently, by reducing the number of slides of the plate in the control of the molten steel flow from a ladle to the tundish, even when a fluctuation in an amount of molten steel in the tundish increases in some degree, such fluctuation can be absorbed by controlling the molten steel flow from the tundish to the mold. Specifically, a control range of the weight of molten steel in the tundish is preferably within ±3 percent by mass, and more preferably within ±1 percent by mass. These control ranges have a smaller influence on the level fluctuation of molten steel in the tundish, and have no harmful effects on a quality of steel to be a product.

[0065] While the embodiments of the present invention have been described above, the present invention is not limited to the above-described embodiments, and other embodiments and various modifications may be made without departing from the scope or spirit of the present invention.

INDUSTRIAL APPLICABILITY

[0066] The present invention can be used in a sliding nozzle device which controls a molten steel flow discharged from a ladle to a tundish. The present invention can automatically optimize sliding conditions of the sliding nozzle device even if operational conditions are changed. Accordingly, a corrosion rate of a plate is reduced, and a life of the plates is drastically improved.

Claims

1. A method of controlling a sliding nozzle device in order to control a flow of molten steel discharged from a ladle to a tundish in continuous casting, the method comprising:

measuring a weight of molten steel in the tundish;
calculating a deviation between the measured value and a reference value of the weight of molten steel; and
outputting control signals at a predetermined cycle, the control signals controlling a sliding distance of a plate, based on the deviation and/or a change rate in the weight of molten steel in the tundish; the method **characterized in that**
an average cumulative sliding rate (%/minute) of the plate is calculated; and
if the average cumulative sliding rate (%/minute) of the plate is out of a preset control range, a sliding rate of the plate is changed within a predetermined setting range.

2. The method of claim 1, **characterized in that** the control range for the average cumulative sliding rate of the plate is between 0.5 %/minute and 18 %/minute.

3. The method of claim 1, **characterized in that** the predetermined setting range for the sliding rate of the plate is between 3 % and 20 %.

4. A method of controlling a sliding nozzle device used with a ladle, **characterized in that** an average sliding rate of a plate included in the sliding nozzle device is between 3 % and 20 %.

5. The method of claim 4, **characterized in that** the number of slides of the plate is between 10 times and 60 times per 60 minutes.

6. The method of any one of claim 1 or 4, **characterized in that** a stroke length of the plate is 1.5 times or more but less than 2 times a bore diameter of the nozzle provided in the plate.

7. A plate used in the method of any one of claim 1 or 4, **characterized by** having the stroke length of 1.5 times or more but less than 2 times the bore diameter of the nozzle.

FIG. 1

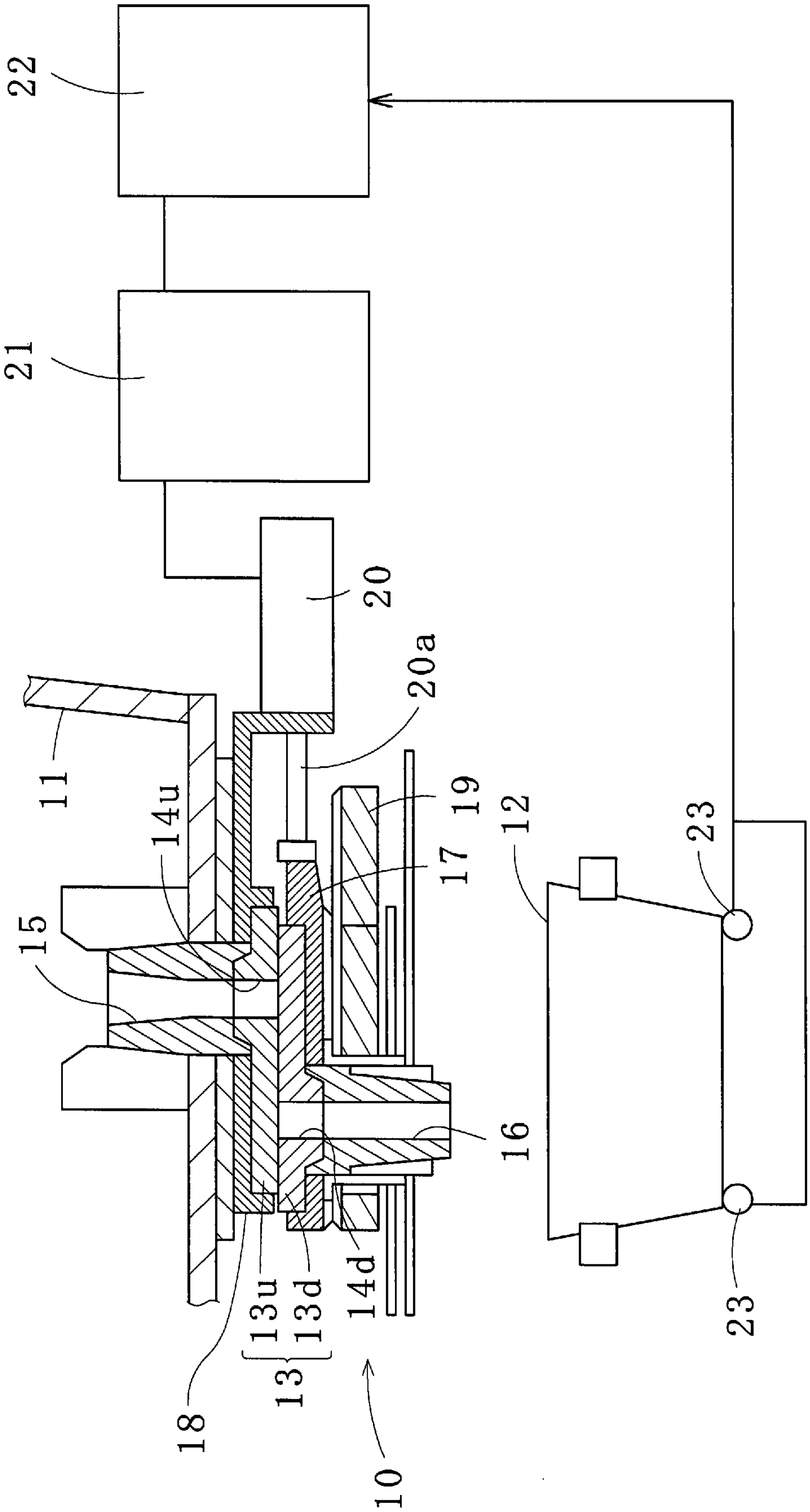


FIG. 2

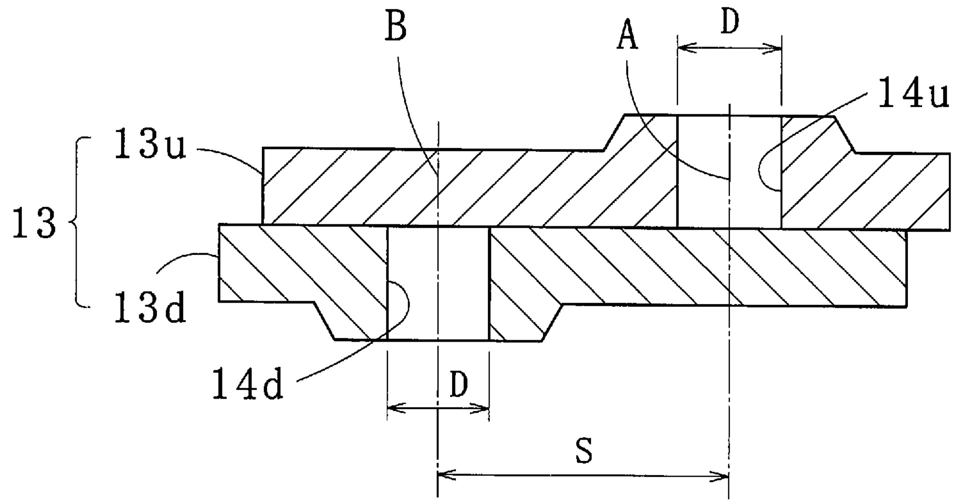


FIG. 3

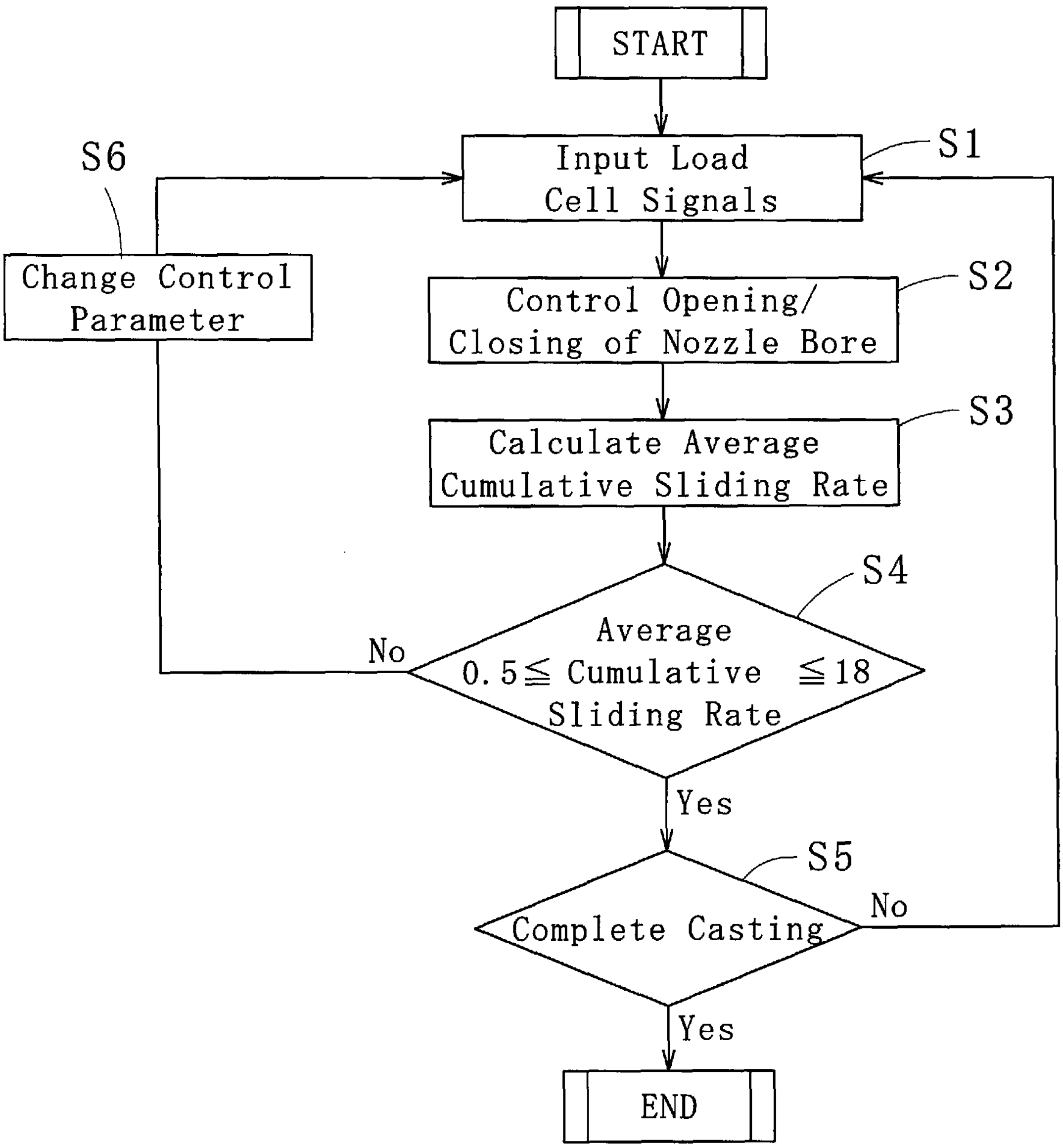

START
Input Load Cell Signals
S1
S6
Change Control Parameter
Control Opening/ Closing of Nozzle Bore
S2
Calculate Average Cumulative Sliding Rate
S3
S4
No
Average 0.5≦ Cumulative ≦18 Sliding Rate
Yes
S5
No
Complete Casting
Yes
END

FIG. 4

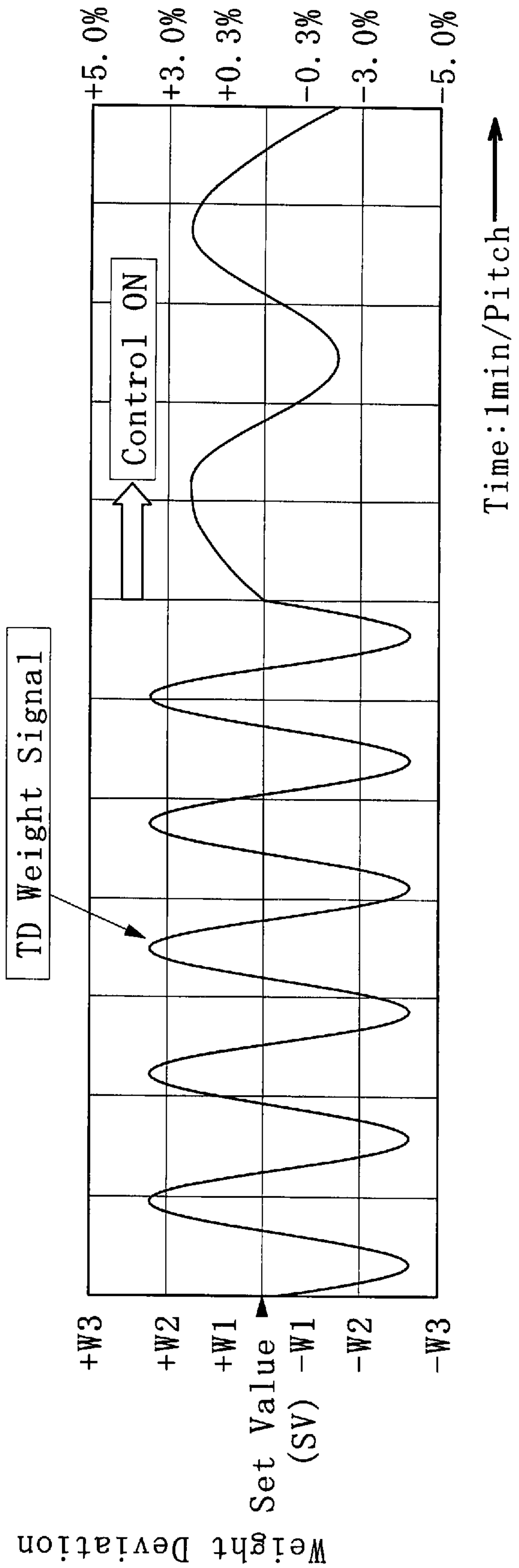

+5.0%
+3.0%
+0.3%
-0.3%
-3.0%
-5.0%
TD Weight Signal
Control ON
Time:1min/Pitch
+W3
+W2
+W1
Set Value
(SV)
-W1
-W2
-W3
Weight Deviation

FIG. 5

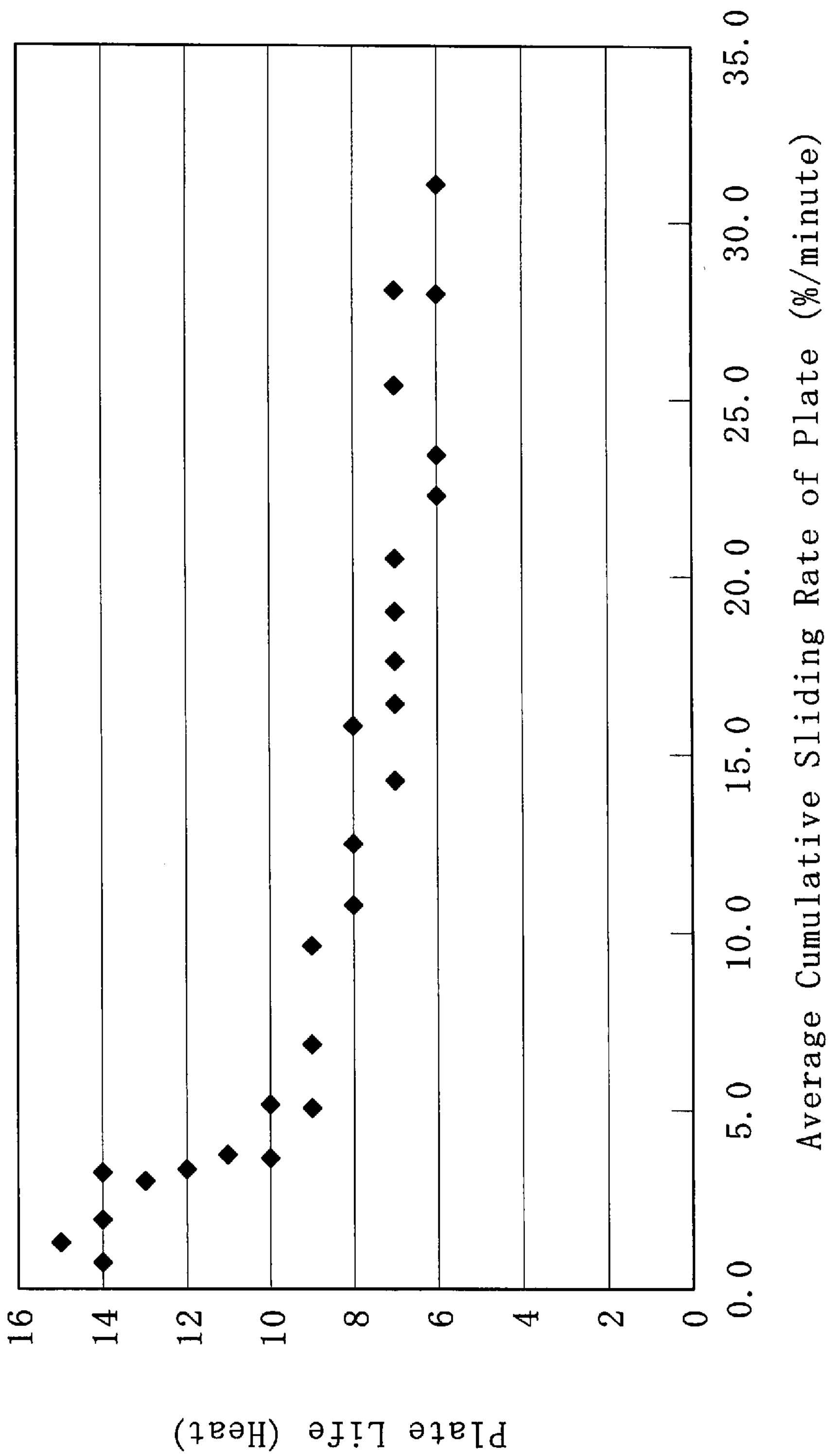


Plate Life (Heat)
Average Cumulative Sliding Rate of Plate (%/minute)
0
2
4
6
8
10
12
14
16
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0

FIG. 6

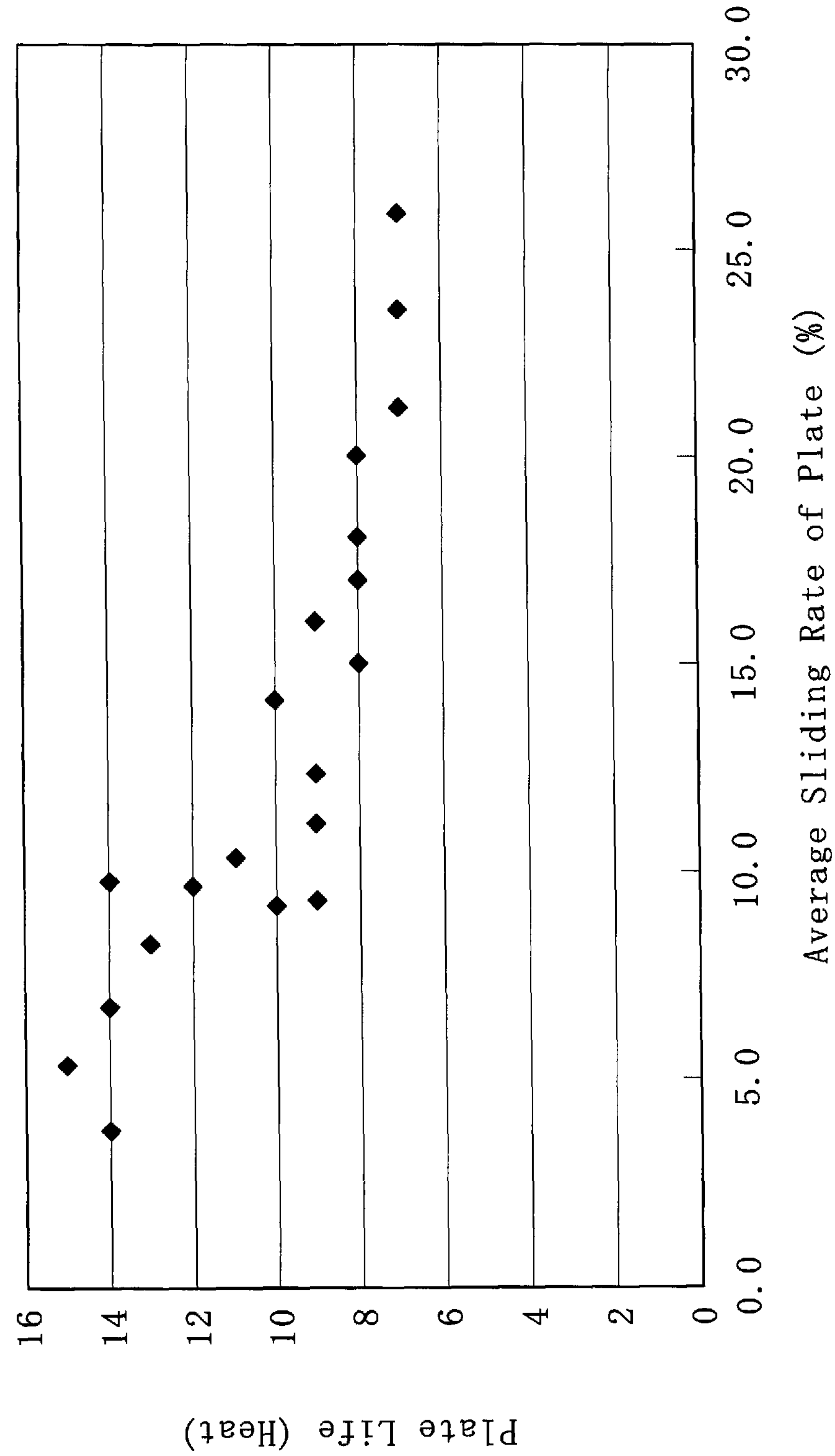


Plate Life (Heat)
16
14
12
10
8
6
4
2
0
Average Sliding Rate of Plate (%)
0.0
5.0
10.0
15.0
20.0
25.0
30.0

FIG. 7

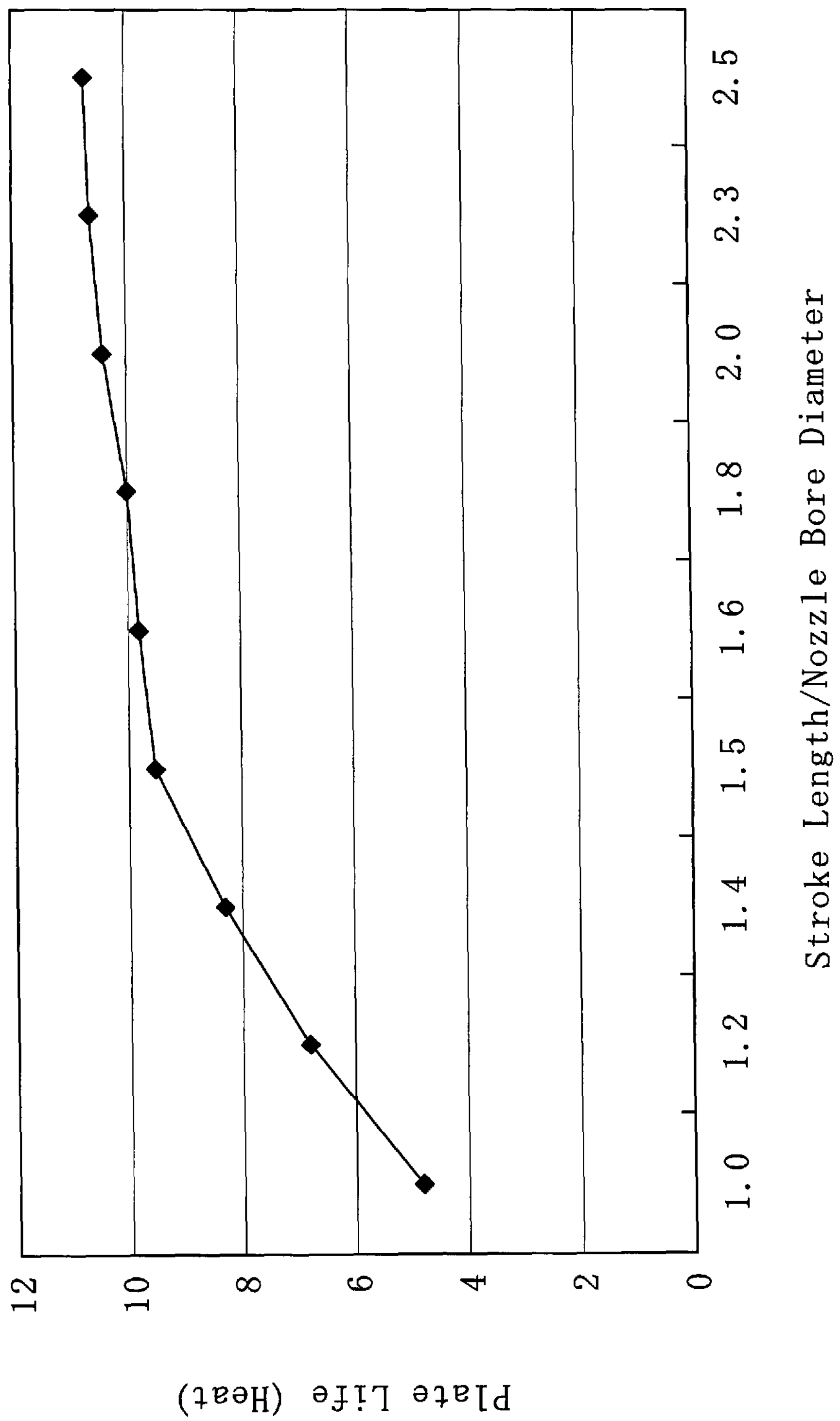


Plate Life (Heat)
0
2
4
6
8
10
12
Stroke Length/Nozzle Bore Diameter
1.0
1.2
1.4
1.5
1.6
1.8
2.0
2.3
2.5

FIG. 8

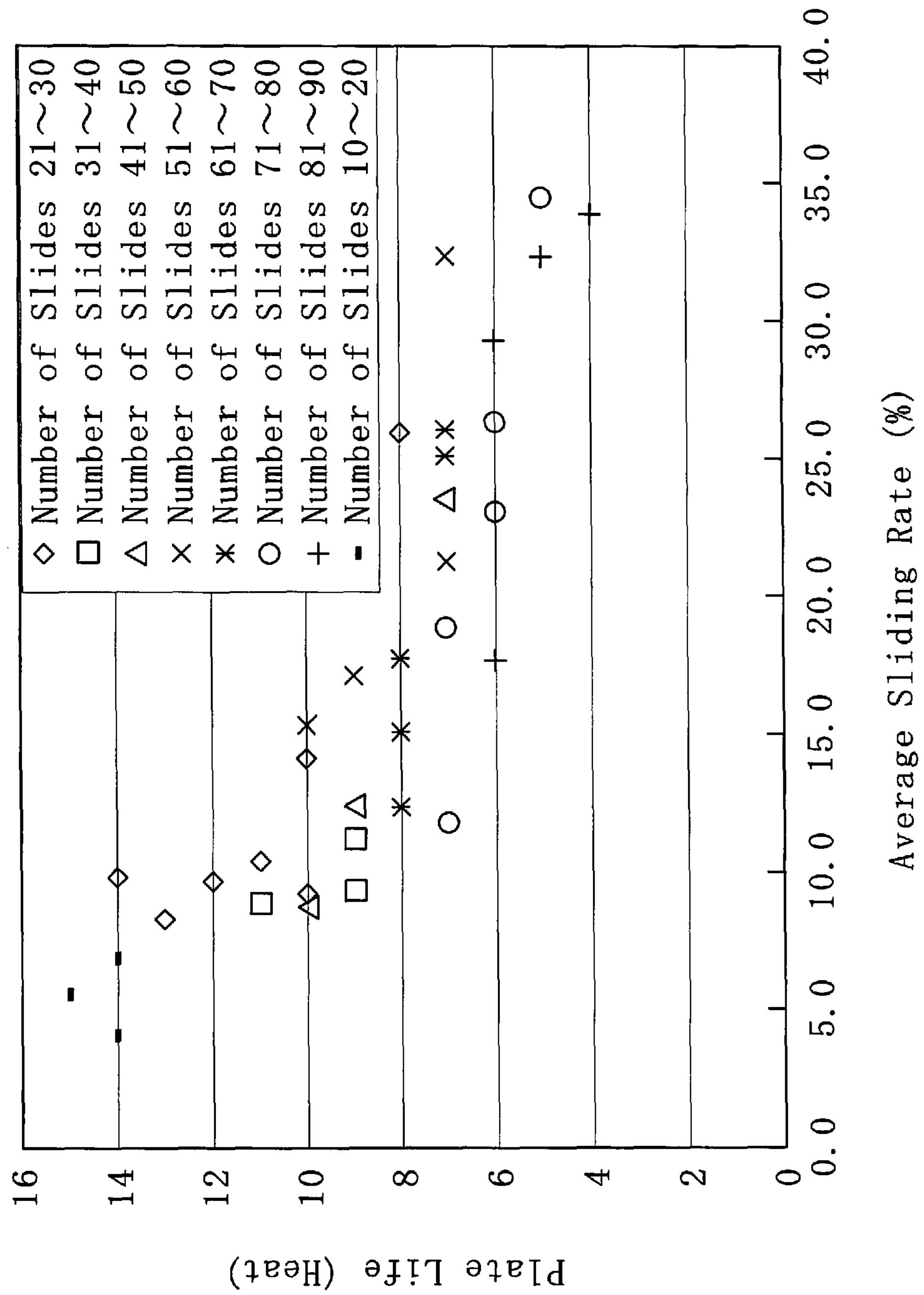

Number of Slides 21～30
Number of Slides 31～40
Number of Slides 41～50
Number of Slides 51～60
Number of Slides 61～70
Number of Slides 71～80
Number of Slides 81～90
Number of Slides 10～20
Plate Life (Heat)
16
14
12
10
8
6
4
2
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Average Sliding Rate (%)

FIG. 9

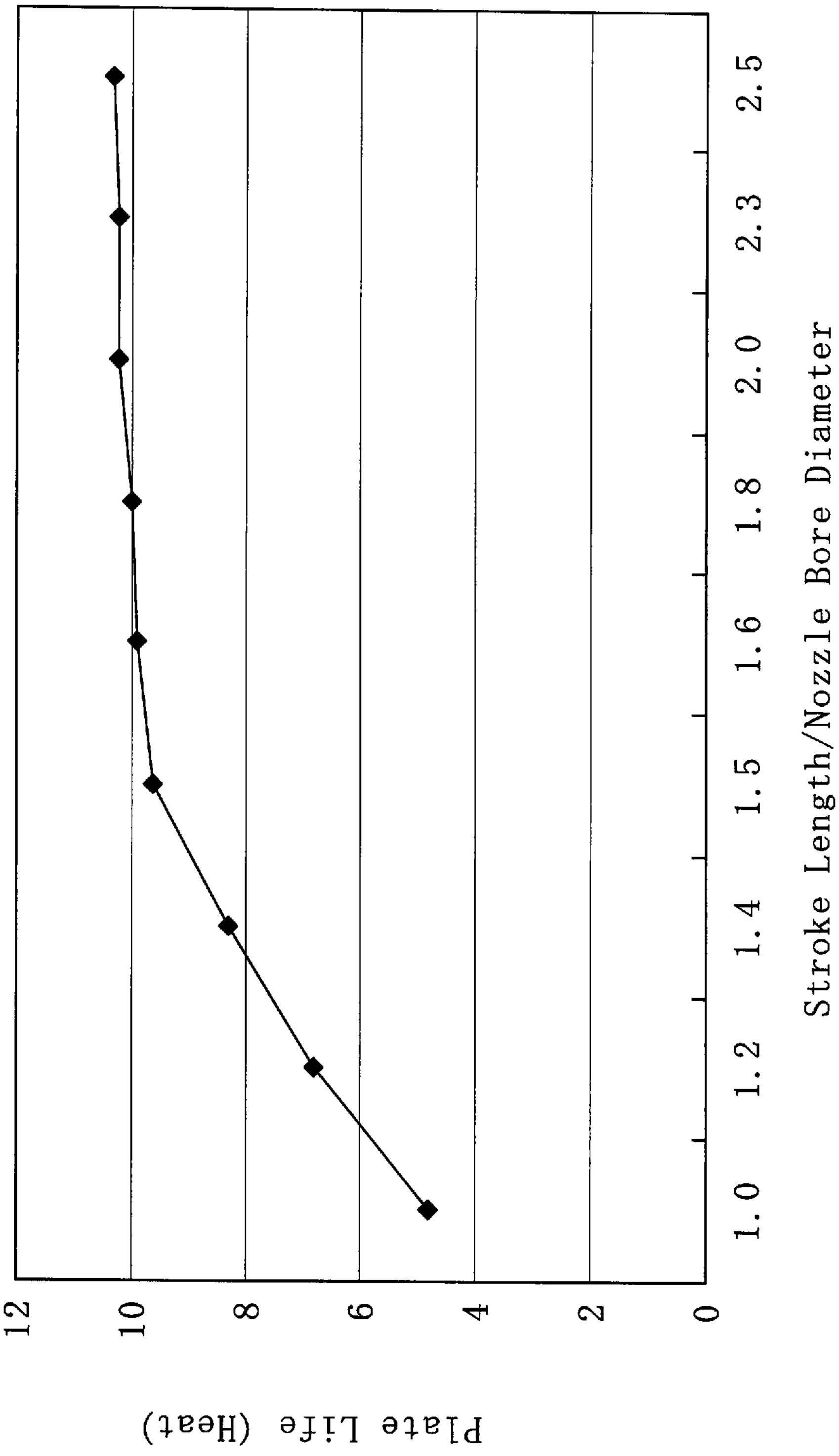


Plate Life (Heat)
0
2
4
6
8
10
12
Stroke Length/Nozzle Bore Diameter
1.0
1.2
1.4
1.5
1.6
1.8
2.0
2.3
2.5

FIG. 10(a)

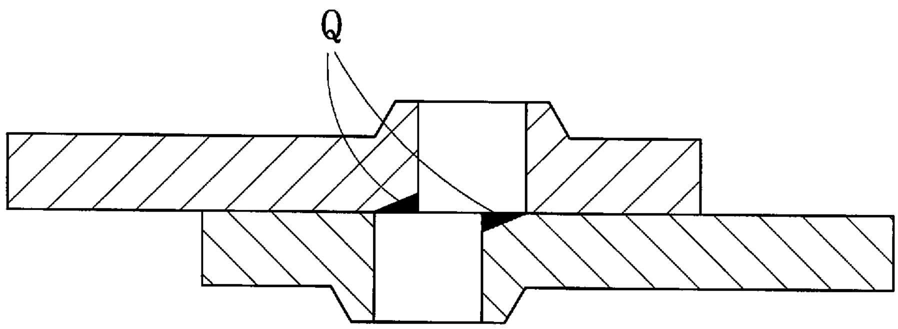
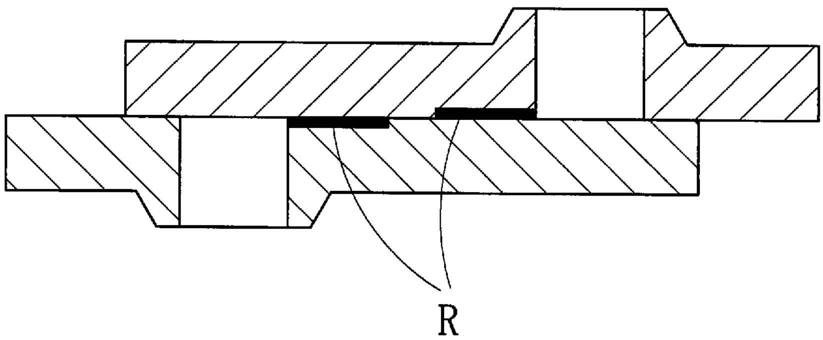


FIG. 10(b)



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/056341

A. CLASSIFICATION OF SUBJECT MATTER
B22D11/10(2006.01)i, *B22D11/18*(2006.01)i, *B22D41/28*(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)
B22D11/10, B22D11/18, B22D41/28

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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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.
Y	JP 62-158557 A (Kurosaki Corp.), 14 July, 1987 (14.07.87), Page 2, upper left column, line 20 to upper right column, line 3 (Family: none)	1-7
Y	JP 62-158556 A (Kurosaki Corp.), 14 July, 1987 (14.07.87), Page 2, upper right column, lines 7 to 10 (Family: none)	1-7

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 May, 2009 (26.05.09)	09 June, 2009 (09.06.09)

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

Form PCT/ISA/210 (second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 62158556 A **[0006] [0058]**
- JP 62158557 A **[0006]**
- JP 2003164951 A **[0006]**
- JP 11138243 A **[0006]**