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D-80538 München (DE)(54) **METHOD OF CASTING CONTINUOUS SLAB.**

(57) When a slab is drawn while a mold formed of a long wall and a short one is vertically vibrated in the process of vertical type continuous casting, said long side wall is moved away from the slab with a hydraulic cylinder (4) actuated in a time zone in which large frictional force acts upon the slab. On the contrary, in a time zone in which large frictional force does not act on the slab, the long side wall having been kept away from the slab is brought closer thereto. In this way, by moving the long side wall away from or closer to the slab repeatedly, a depth of oscillation mark is reduced so that a slab with less segregation at the valley of oscillation mark may be obtained.

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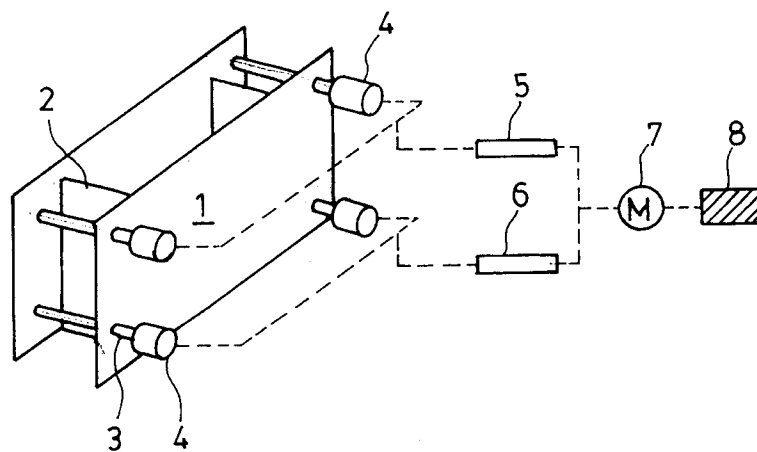


Fig. 3

Technical Field

The present invention relates to a casting process for continuous castings, capable of obtaining the castings reduced in the depths of oscillation marks and suppressed in segregation at oscillation mark trough portions, in a continuous casting method, particularly, a vertical continuous casting method for metal.

Background Art

Conventionally, for the purpose of eliminating the repairing work for the surfaces of continuous castings, there has been proposed a technique of oscillating a vertical mold for reducing or preventing positive segregations at oscillation mark trough portions on the surfaces of the castings, particularly, in casting stainless steel (SUS 304). For example, Japanese Patent Laid-open No. hei 2-290656 has disclosed such a technique that, in a continuous casting mold of a type forming a casting space with two pairs of mold wall surfaces, a pair of the mold wall surfaces are relatively separated from each other only for a negative strip time zone in vertical oscillation or for a mold descending time zone.

This technique is recognized to be considerably effective as compared with a case of giving only simple vertical oscillation. However, as a result of an experiment, it is seen that the technique is not much effective for such a case that the oscillation frequency $\langle f \rangle$ of the mold is small. Further, in the above technique, the consumption of mold powder is reduced, thereby causing the breakout due to sticking. Accordingly, on the contrary, there is arisen an inconvenience of obstructing the stable casting.

Conventionally, the mechanism and cause of generating the segregations at oscillation mark trough portions were considered as follows: namely, the negative pressure is generated within a liquid phase lubricating film between the mold and the solidified shell due to oscillation of the mold; and due to this negative pressure, the non-solidified and concentrated molten steel between dendrites of the solidified surface layer permeates onto the surface of the shell.

However, as a result of the examination on the segregated portions of the casting by the present inventors, it was revealed that the segregation is generated in accordance with such a mechanism that the continuous growth of the solidified shell is obstructed by breaking of the shell due to a tensile force applied thereto and by buckling due to a compressive force, and thereby the concentrated liquid flows out from the broken portions or buckled portions of the shell to the surface of the shell. Accordingly, for preventing the segregation, it is effective to prevent the breaking or the buckling of the shell at the beginning of the solidification, that is, to simultaneously reduce the tensile force and the compressive force applied to the shell.

An object of the present invention is to provide a process of withdrawing the continuous castings wherein, even in the low cycle condition that the oscillation frequency $\langle f \rangle$ of the mold is small, the segregations at oscillation mark trough portions on the surfaces of the castings are significantly reduced to the degree equivalent to that in the high cycle condition, and also the stable casting is made possible.

Disclosure of the Invention

In a preferred mode of the present invention, there is provided a casting process for continuous castings characterized by vertically oscillating a vertical continuous casting mold forming a casting space with two pairs of mold wall surfaces; and simultaneously repeating a series of actions composed of separating at least a pair of mold wall surfaces from a solidified shell at any period in each specified time zone within a positive strip time zone and a negative strip time zone, and of making the separated mold wall surfaces close to the solidified shell within the other time zones.

Further, preferably, there is provided a casting process for continuous castings characterized by performing the casting under the condition of only a positive strip time zone, while vertically oscillating a vertical continuous casting mold forming a casting space with two pairs of mold wall surfaces; and repeating a series of actions composed of separating at least a pair of mold wall surfaces from a solidified shell at any period in each specified time zone within a mold ascending period and a mold descending period, and making the separated mold wall surfaces close to the solidified shell within the other time zones in the mold ascending period and the descending period.

Brief Description of the Drawings

Fig. 1 is a graph showing the changes in the vertical oscillating velocity of a mold and the horizontal displacement of the mold walls with time according to an embodiment of the present invention;

Fig. 2 is a graph showing the changes in the vertical oscillating velocity of a mold and the horizontal displacement of the mold walls with time according to another embodiment of the present invention;

Fig. 3 is a schematic perspective view showing a mold horizontally moving apparatus used in the embodiments of the present invention;

5 Fig. 4 is a typical view showing an oscillation mark and a segregated layer;

Fig. 5 is graphs showing an oscillation waveform of the conventional mold, and the retarding and advancing timings thereof; and

Fig. 6 is a typical view showing the portion between the mold wall and the solidified shell.

10 Best Mode for Carrying Out the Invention

As shown in Fig. 1, when a mold reaches the uppermost point, the vertical velocity V_m of the mold becomes 0. Subsequently, as the mold is started to be descended, the velocity V_m is gradually increased. Thus, when the mold reaches the lowermost point, the velocity V_m becomes 0. When the mold is started to
15 be ascended again, the velocity V_m of the mold is increased. Also, in terms of the relative relationship between the vertical velocity of the mold and the withdrawing velocity V_c of the casting, the time for which the vertical velocity V_m of the mold is smaller than the withdrawing velocity V_c is referred to as " negative strip time T_N .

In vertical oscillation of the mold as shown in Fig. 1, at any period in a time zone from the time t_1 to t_2
20 for which the relative velocity ($=V_m-V_c$) is larger within a positive strip time T_p for which the solidified shell is applied with a tensile force, at least a pair of mold walls are horizontally retarded in a manner to be relatively separated from the solidified shell, to be thus opened at the position of X_o . In absence of the negative strip time T_N ($T_N = 0$), as shown in Fig. 2, at any period in a time zone from the time t_4 to t_5 for which the relative velocity is larger within a mold ascending time, at least a pair of mold walls are retarded
25 in a manner to be relatively separated from the solidified shell, to be thus opened at the position of X_o .

Thus, as shown in Fig. 6, a distance between a mold wall 9 and a solidified shell 12 is increased from X_s to X_o , so that a mold powder 10 on a molten steel 11 is made to sufficiently flow in a gap between the mold wall 9 and the solidified shell 12 to thereby reduce the frictional force between the mold wall 9 and the solidified shell 12. In addition, the arrow of Y indicates the direction of withdrawing the casting.

In Fig. 1, at any period in a subsequent time zone from the time t_3 to t_4 for which the relative velocity is smaller within the negative strip time T_N for which the compressive force is applied to the shell, the mold walls are relatively separated from the solidified shell, to be thus opened at the position of X_o . In absence of
30 no negative strip time T_N ($T_N = 0$), as shown in Fig. 2, at any period in a time zone from the time t_2 to t_3 for which the relative velocity is smaller in a mold descending time, at least a pair of mold walls are retarded in a manner to be relatively separated from the solidified shell, to be thus opened at the position of X_o . In absence of the negative strip, since the relative velocity between the mold and the solidified shell is usually directed upwardly, it is considered that the shell is not applied with the compressive force. However, since the solidified shell at the meniscus portion within the mold is continuously grown and the position thereof is made constant, the shell is applied with the compressive force even in the case of $T_N = 0$.
35

For the time zones other than those described above, that is, for the time zones from the time t_2 to t_3 and from the time t_4 to t_5 in Fig. 1, and the time zones from the time t_1 to t_2 and from the time t_3 to t_4 in Fig. 2, the mold walls are advanced to be close to the solidified shell, to be thus closed at the position of X_s . Namely, the distance X between the mold and the solidified shell is changed from X_o to X_s . In the case
40 of giving the horizontal oscillation to the mold for changing the distance between the mold wall surfaces and the solidified shell, particularly, the frictional force applied to the initial solidified shell of the meniscus portion can be calculated, under the consideration of the frictional force between the mold and the solidified shell, as the shear force applied between the mold and the solidified shell by the following equation:
45

$$F = A \cdot \mu \cdot (dV / dX) \quad (1)$$

50

wherein

A : contact area between mold and solidified shell

μ : viscosity of mold powder flown in space between mold wall and solidified shell

dV : relative velocity between mold wall and solidified shell ($=V_m-V_c$)

55

X : distance between mold and solidified shell

As is apparent from the above equation (1), the frictional force F applied to the solidified shell is reduced at the period for which the distance X between the mold and the solidified shell is enlarged. Namely, according to the present invention, it is possible to significantly reduce the tensile force and the

compressive force applied to the shell of the meniscus portion at the beginning of the solidification. Consequently, the continuity of the solidified shell is held, thereby making it possible to narrow the depths of the oscillation marks, and to reduce the possibility of generating the segregation at the oscillation mark trough portions as compared with the conventional technique.

5 The effect describe above is not much dependent on the vertical oscillation waveform and a waveform for horizontally advancing/retarding (closing/opening) the mold walls (hereinafter, referred to as "horizontal oscillation"), and which is similarly effective in the cases of the non-sinusoidal wave or triangular wave other than the vertical oscillation of the sinusoidal wave and the horizontal wave of the trapezoidal wave as shown in Fig. 1. In addition, for preventing molten steel from permeating in the gaps at the mold corners thereby
10 bringing about a fear of causing the sticking induced breakout, the amplitude of the horizontal oscillation is preferably within the range of 1mm or less.

Hereinafter, the present invention will be described in detail with reference to examples.

Example 1

15

As shown in Fig. 3, a horizontal oscillator generally used for a slab continuous casting machine has a mechanism of clamping mold short sides 2 with mold long sides 1 through short side clamping springs 3. In the present invention, there is provided a hydraulic circuit for opening/closing a short side clamping
20 hydraulic cylinder 4, so that the long sides 1 of the mold is moved by opening and closing the short side clamping hydraulic cylinder 4 through upper and lower solenoid valves 5 and 6 provided in a hydraulic circuit. Numeral 7 indicates a hydraulic motor and numeral 8 is a hydraulic tank. If the gaps between the long sides and short sides of the mold are made excessively larger, molten steel permeates in the gaps, thereby causing the trouble. Accordingly, the retarded amount of the long sides of the mold is within the range of 1mm or less.

25

The casting of stainless steel (SUS 304) was continuously cast using the above horizontal oscillator for horizontally oscillating the mold walls as shown in Fig. 3. In the above casting, from the depth d_1 , at an oscillation mark 13 (see Fig. 4) and the segregation layer depth d_2 at the segregation mark portion on the surface of the casting, the segregation layer thickness ($d_2 - d_1$) at the oscillation mark portion was obtained. Thus, the examination was made for the above segregation layer thickness ($d_2 - d_1$) and the segregation
30 layer depth d_2 . For comparison, the examinations were made for the cases of generating only the vertical oscillation (sinusoidal wave) according to the conventional manner; and of generating such oscillating waves as shown in Figs. 5(a) and 5(b) disclosed in Japanese Patent Laid-open No. Hei 2-290656. In the above, Fig. 5(a) shows the case of moving the mold walls backward during the period when the oscillation of the mold lies in the negative strip time. Besides, Fig. 5(b) shows the case of retarding the mold in the mold descending period. In addition, the casting condition of the present invention is as follows: withdrawing
35 velocity V_c of castings = 1.2/min; mold vertical oscillating frequency f = 150 times/min; amplitude S = 5.3mm; vertical oscillating waveform = sinusoidal curve; horizontal oscillating amplitude = 0.3mm; horizontal oscillating pattern is trapezoidal wave (see Fig. 1). Further, the mold wall opening/closing timing is closed (at the position of X_s) for a period from 105° to 130° (from the time t_2 to t_3 in Fig. 1) in terms of
40 angle conversion (zero angle, when V_m is positively maximized), and a period from 240° to 275° (from the time t_4 to t_5 in Fig. 1), and is opened (at the position of X_o) for the other periods. The moving velocity from the opening to the closing, or the closing to the opening was specified at 50mm/sec. In addition, as the mold power, there was used a lubricant having a viscosity of 1.1 poise at 1300°C and the solidification temperature of 900°C .

45

Example 2

Next, for the case of no negative strip time ($T_N 0$), the test was carried out in the same manner as in Example 1, except that the amplitude S of the mold vertical oscillation was 2.0mm, and the horizontal
50 opening and closing timing was closed in the period from 110° to 160° (from the time t_1 to t_2 in Fig. 2) and in a period from 250° to 290° (from the time t_3 to t_4 in Fig. 2), and was opened in the other periods.

The results obtained in Examples 1 and 2 are shown in Table 1 as compared with the conventional manner. It becomes apparent from Table 1 that, as compared with the conventional manner, the present invention makes it possible to significantly reduce the rate of generating the segregations at the oscillation
55 trough portions to the degree of being almost zero.

Table 1

No.	Oscillation Type	Vertical oscillation of mold		Condition of horizontal oscillation	Segregation		Oscillation mark depth d2 (mm)	Remark
		Amplitude (mm)	Frequency (cpm)		Thickness d2 - d1 (mm)	Generation rate (%)		
1	Conventional	5.3	150	Horizontal oscillation, not applied	0.35	67	0.42	T _N >0
		2	300	Horizontal oscillation, not applied	0.10	25	0.15	T _N >0
2	Conventional	5.3	150	Open in negative period	0.20	43	0.37	T _N >0
3	Conventional	2	150	Open in mold descending period	0.18	34	0.32	T _N =0
4	Present invention	5.3	150	Condition of present invention (see Fig. 1)	0	0	0.21	T _N >0
5	Present invention	2	150	Condition of present invention (see Fig. 2)	0	0	0.15	T _N =0

Industrial Applicability

By provision of a mold oscillation method of horizontally opening and closing (retarding and advancing) the mold walls from and to the solidified shell according to the mold vertical oscillating timing for extremely reducing the compressive force and the tensile force applied to the initial solidified shell, it is possible to

significantly reduce the segregations at the oscillation trough portions on the surface of the casting. As a result, the following effects can be obtained:

- 5 (1) By eliminating the need of performing the casting under the high cycle mold oscillating condition having a fear of causing the generation of the sticking induced breakout, it is possible to reduce the trouble in productivity.
- (2) In the case of stainless steel (SUS 304), since it is possible to reduce the amount to be cut by a grinder for removing the segregations before the heating and rolling processes as in the conventional manner, and further to supply the casting to the next process with no repairing in the specific case, the improvement in yield can be expected.

10 Claims

1. A casting process for continuous castings characterized by
 - 15 vertically oscillating a vertical continuous casting mold forming a casting space with two pairs of mold wall surfaces; and
 - simultaneously repeating a series of actions composed of separating at least a pair of mold wall surfaces from a solidified shell at any period in each specified time zone within a positive strip time zone and a negative strip time zone, and of making said separated mold wall surfaces close to said solidified shell within the other time zones.
2. A casting process for continuous castings characterized by
 - performing the casting under the condition of only a positive strip time zone, while vertically oscillating a vertical continuous casting mold forming a casting space with two pairs of mold wall surfaces; and
 - 25 repeating a series of actions composed of separating at least a pair of mold wall surfaces from a solidified shell at any period in each specified time zone within a mold ascending period and a mold descending period, and making said separated mold wall surfaces close to said solidified shell within the other time zones.

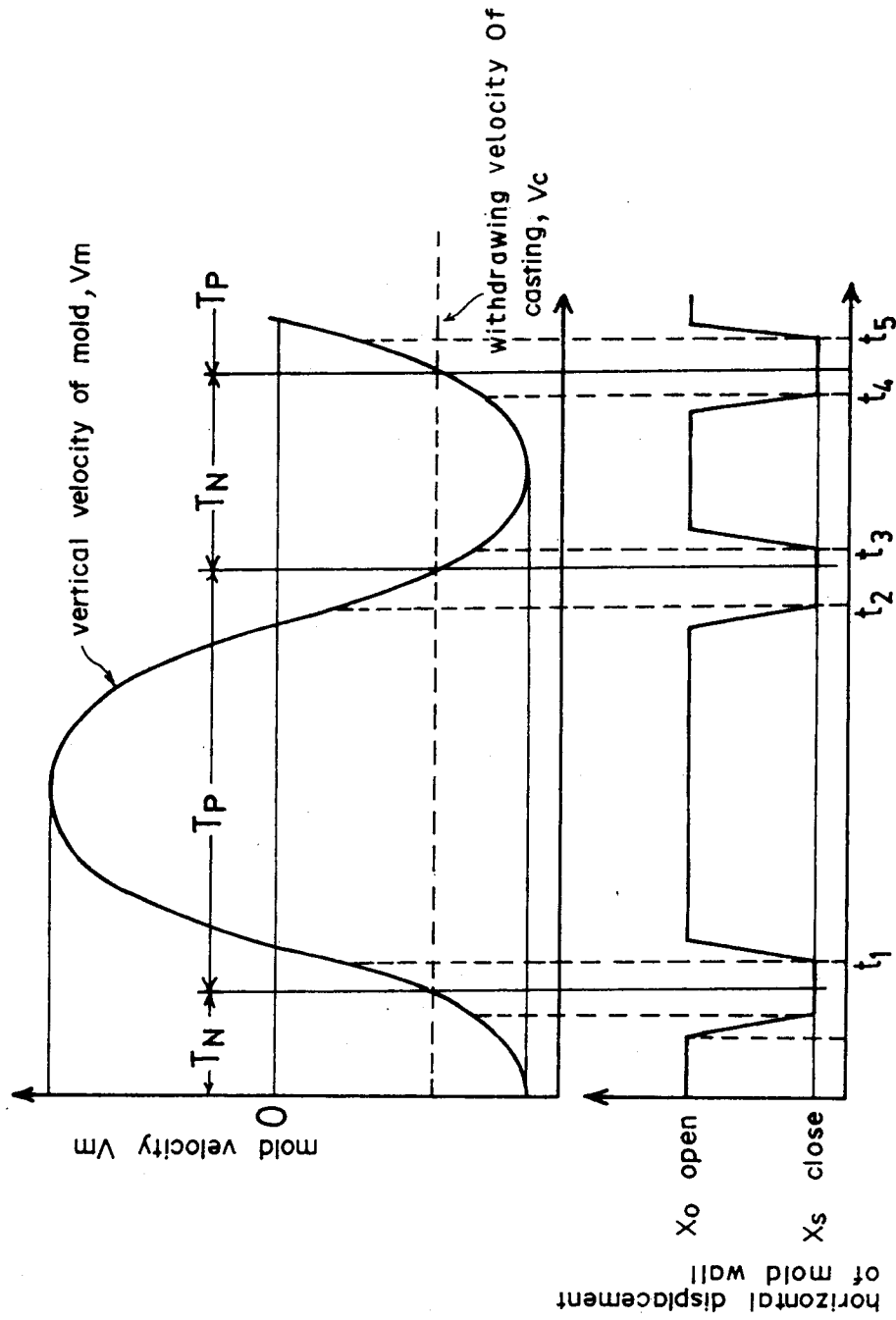


Fig. 1

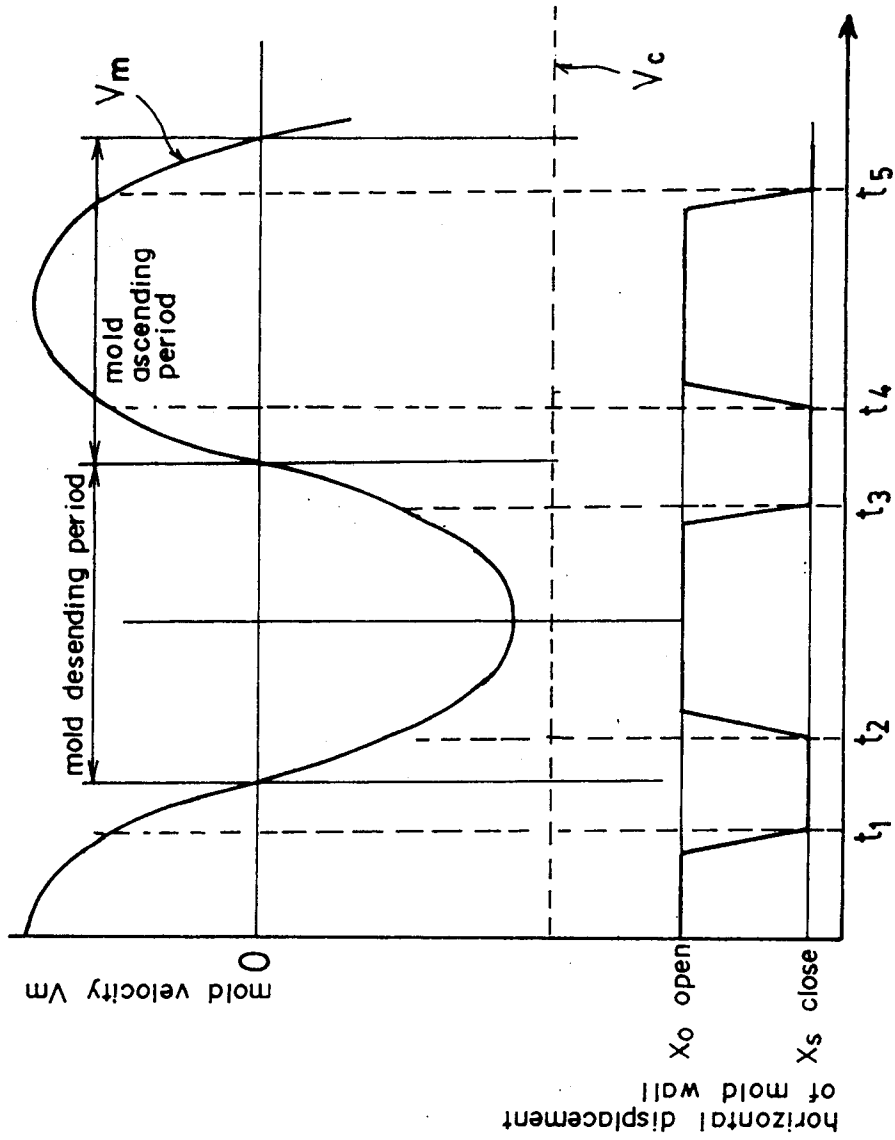


Fig. 2

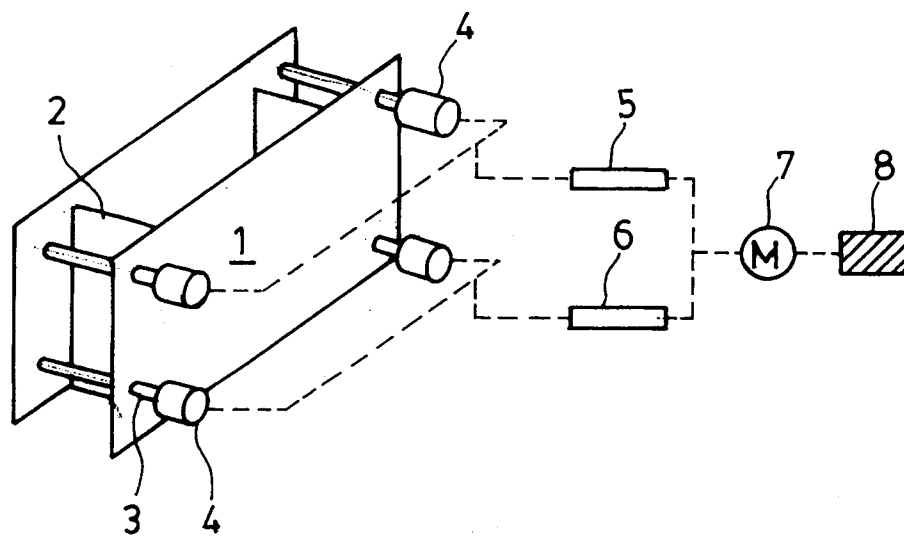


Fig . 3

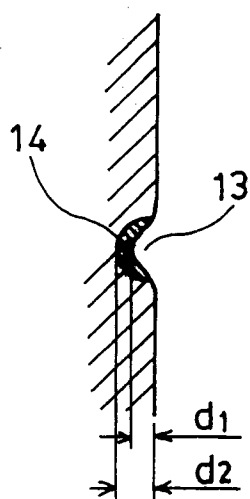


Fig . 4

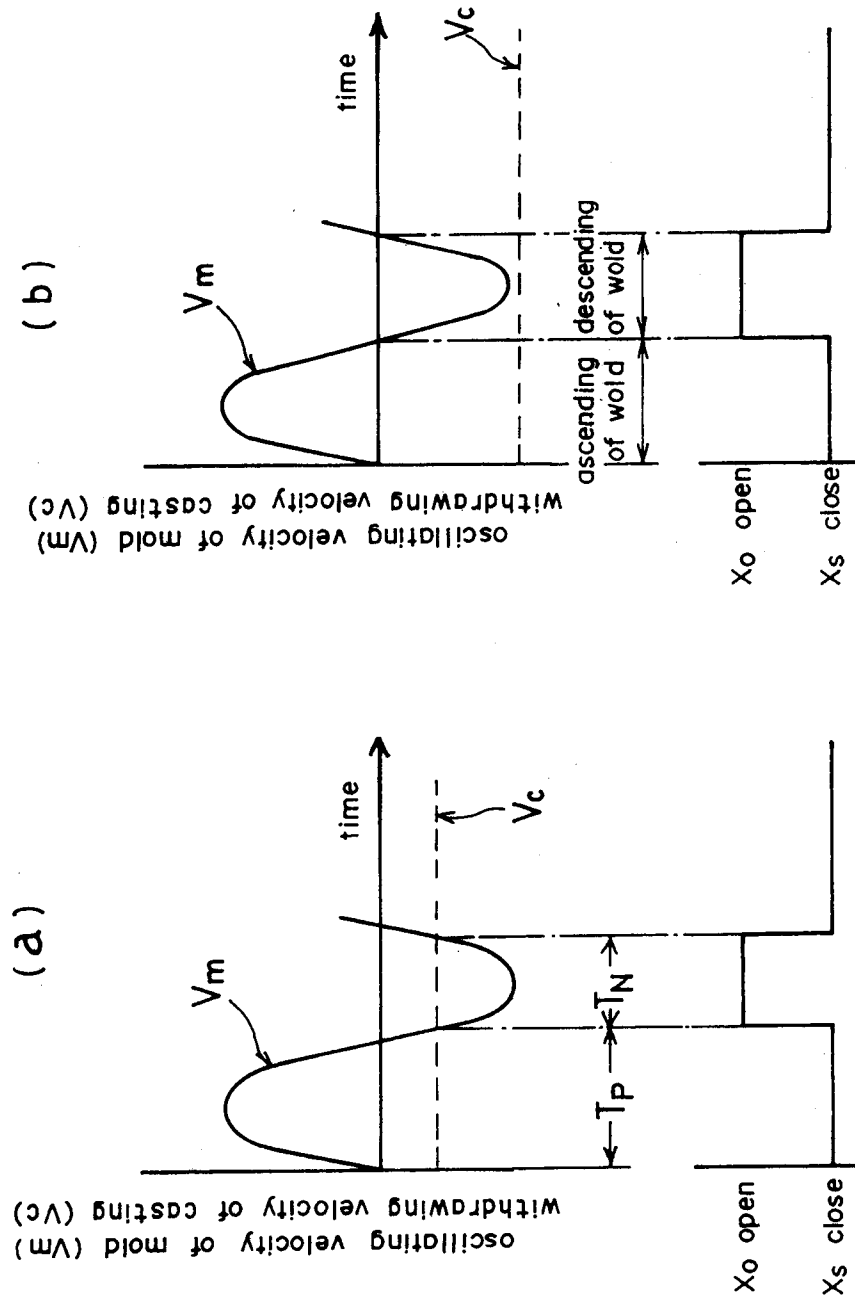


Fig. 5

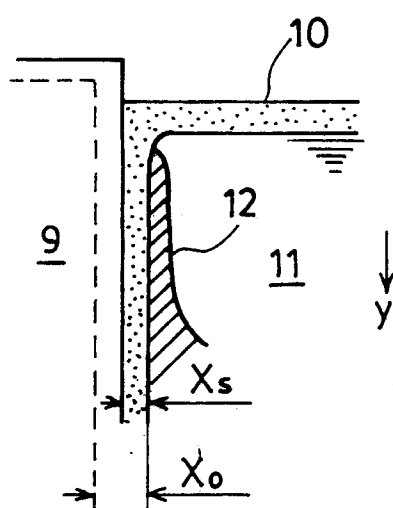


Fig. 6

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP92/01205

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl ⁵ B22D11/04, 11/16		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC	B22D11/04, 11/16	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
Jitsuyo Shinan Koho	1926 - 1992	
Kokai Jitsuyo Shinan Koho	1971 - 1992	
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
Y	JP, A, 4-143057 (Kawasaki Steel Corp.), May 18, 1992 (18. 05. 92), (Family: none)	1, 2
Y	JP, A, 3-297546 (Kawasaki Steel Corp.), December 27, 1991 (27. 12. 91), (Family: none)	1, 2
A	JP, A, 3-99756 (Kawasaki Steel Corp.), April 24, 1991 (24. 04. 91), (Family: none)	1, 2
Y	JP, A, 2-290656 (Kawasaki Steel Corp.), November 30, 1990 (30. 11. 90), (Family: none)	1, 2
A	JP, A, 64-18553 (Kawasaki Steel Corp.), January 23, 1989 (23. 01. 89), (Family: none)	1, 2
* Special categories of cited documents: ¹⁰ "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document 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 "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 "Z" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
November 10, 1992 (10. 11. 92)	December 1, 1992 (01. 12. 92)	
International Searching Authority	Signature of Authorized Officer	
Japanese Patent Office		