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(54) **METHOD OF MONITORING FOR DAMAGE TO SOLIDIFIED SHELL OF METAL CASTING PRODUCE DURING REMOVAL OF CASTING FROM HORIZONTAL CONTINUOUS CASTING MACHINE.**

(57) This method monitors for damage within a horizontally mounted mold to a solidified shell of a casting of molten metal produced by the horizontal and continuous removal of the casting from the mold, by a plurality of clamping rods, via a brake ring, on a feed nozzle mounted horizontally in an opening in the lower part of a side wall of a tundish containing molten metal. The method comprises the steps of continuously measuring the strain on any of at least one of said plurality of rods and a sleeve engaging with at least one of said plurality of rods, and monitoring for damage within the mold to the shell of the casting by taking an abrupt change in the measured strain to be due to damage to the shell of the casting within the mold.

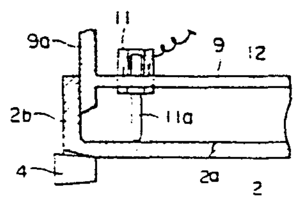

FIG. 4

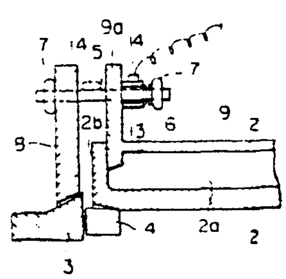

FIG. 6

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SPECIFICATION

TITLE OF THE INVENTION

METHOD FOR MONITORING BREAKAGE OF SOLIDIFIED SHELL OF CAST METAL STRAND, WHICH MAY OCCUR WHEN WITHDRAWING CAST METAL STRAND FROM HORIZONTAL TYPE CONTINUOUS CASTING MACHINE

FIELD OF THE INVENTION

The present invention relates to a method for monitoring a breakage of a solidified shell of a cast metal strand in a mold, which may occur when horizontally withdrawing the cast metal strand intermittently and continuously from the mold of a horizontal type continuous casting machine.

BACKGROUND OF THE INVENTION

The horizontal type continuous casting method of a cast metal strand is recently being industrialized, which comprises horizontally withdrawing the cast metal strand intermittently and continuously from a mold horizontally fitted to an opening provided at the lower portion of the side wall of a tundish containing a molten metal.

Fig. 1 is a schematic descriptive sectional view illustrating an instance of the connecting section between a tundish and a mold in a conventional horizontal type continuous casting machine. In Fig. 1, ~~1 is a tundish~~ for containing a molten metal, and 2 is a mold having a casing 9, horizontally fitted to an opening 1a provided at the lower portion of the tundish 1. A space 12 for circulating cooling water for cooling the mold 2 is formed between the mold 2 and the casing 9.

In Fig. 1, 3 is a feed nozzle horizontally fitted to the opening 1a provided at the lower portion of the tundish 1, and 4 is a break ring horizontally fitted between an end of the feed nozzle 3 and the inlet of the mold 2. The outer periphery of the end of the feed nozzle 3 in contact with the break ring 4 has an inclined face extending toward outside. The outer periphery of an end of the break ring 4 in contact with the mold 2 has an inclined face directed toward inside. The break ring 4 engages with the inside of the inlet of the mold 2 having an inclined face matching with the inclined face of the break ring 4.

In Fig. 1, 8 is an annular clamping plate having a bore at the center thereof, matching with the inclined face of the feed nozzle 3, and the inclined face of the feed nozzle 3 is engaged with the bore of the clamping plate 8. The mold 2 has a flange 2b at the inlet thereof, and the casing 9 has also a flange 9a. The flange 9a of the casing 9 is fixed to the flange 2b of the mold 2.

The flange 9a of the casing 9 is secured to the clamping plate 8 by means of a plural sets of a tightening rod 5 and a nut 7 passing through a plurality of through-holes provided along the outer peripheral edges of the clamping plate 8 and the flange 9a of the casing 9. A spring 6 is provided at an end of each of the tightening rods 5.

By tightening the nuts 7, therefore, the casing 9, the mold 2, the break ring 4, and the feed nozzle 3 are integrally and elastically connected through the intermediary of the plurality of tightening rods 5 and the plurality of springs 6. Hydraulic cylinders may be used in place of the above-mentioned springs 6.

With the above-mentioned horizontal type continuous casting machine, a cast metal strand is cast as follows: The molten metal contained in the tundish 1 is horizontally withdrawn intermittently and continuously from the mold 2 provided horizontally at the lower portion of the tundish 1 while forming a solidified shell in the mold 2, through a plurality of cycles each comprising a pull and a push. Thus, a cast metal strand is continuously cast.

Fig. 2 is a descriptive graph illustrating an instance of a conventional cycle comprising a pull and a push for horizontally withdrawing a cast metal strand from the mold as described above. In Fig. 2, the abscissa represents time, and the ordinate indicates the pulling speed in the upper half starting from point 0, and the compressive force applied on the cast strand by the push of the cast strand in the lower half starting from point 0.

Figs. 3(a) and 3(b) are descriptive drawings illustrating shell formation of the cast metal strand in the mold 2 when horizontally withdrawing the cast metal strand intermittently and continuously from the mold 2 by the above-mentioned method. Fig. 3(a) shows shell formation of the cast metal strand during withdrawal in a cycle comprising a pull and a push, whereas Fig. 3(b), shell formation of the cast metal strand upon completion of a cycle comprising a pull and a push. The molten metal which flows from the tundish 1 containing the molten metal into the mold 2 is cooled by the mold 2 and the break ring 4 to form a solidified shell 10 as shown in Figs. 3(a) and 3(b). A cast metal strand having the thus formed solidified shell 10 is horizontally withdrawn intermittently and continuously from the mold 2 while increasing the thickness of the solidified shell.

However, an abnormality may cause breakage of the solidified shell 10 of the cast strand in the mold 2 at the time of the pull in the next cycle. Fig. 3(c) is a descriptive drawing illustrating a breakage of the solidified shell 10. As shown in Fig. 3(c), if withdrawal of the cast strand from the mold 2 is continued with a breakage occurring in the mold 2, a breakout of the cast strand occurs at the exit of the mold 2, and this may cause a serious accident and make it impossible to conduct further casting.

In order to avoid such a difficulty, it is necessary to temporarily discontinue withdrawal of the cast strand from the mold 2 immediately upon occurrence of a breakage of the solidified shell 10 of the cast strand in the mold 2, and cool and solidify molten metal having penetrated into the broken portion to cause welding thereof. It is therefore necessary to constantly monitor, during withdrawal of the cast strand from the mold 2, the occurrence of a breakage of the solidified shell 10 formed in the mold 2.

For the purpose of preventing the occurrence of a breakout of the cast strand, the following method for monitoring a breakage of a solidified shell in a mold is known:

A method, disclosed in Japanese Patent Publication No. 49-26,812 dated July 12, 1974, which comprises:

continuously measuring, while horizontally withdrawing a cast strand of a metal intermittently and continuously, by a plurality of cycles each comprising a pull and a push, from a mold horizontally fitted by a plurality of tightening rods through the intermediary of a break ring to a feed nozzle horizontally fitted to an opening provided at the lower portion of the side wall of a tundish containing a molten metal, the temperature of said mold by a thermocouple built in the mold wall near the position at which a solidified shell is first formed; and deeming a sudden decrease in said measured temperature as representing the occurrence of a breakage of the solidified shell of said cast strand in said mold to monitor the breakage of said solidified shell of said cast strand in said mold (hereinafter referred to as the "prior art").

In the above-mentioned prior art, the occurrence of a breakage of the solidified shell of the cast strand in the mold can be detected by means of sudden change in the temperature of the mold for the following reasons: As shown in Fig. 3(c), when the solidified shell 10 of the cast strand is broken in the mold 2, the portion of the mold 2 in association with the solidified shell 10 left on the side of the break ring 4 is prevented from coming into direct contact with the high-temperature molten metal in the mold 2 by the remaining solidified shell 10, thus causing a sudden decrease in the temperature. Therefore, it is possible to monitor a breakage of the solidified shell 10 by building a thermocouple in the wall of the mold 2 near the position at which the solidified shell 10 is first formed, and continuously measuring the temperature of this portion of the mold 2.

However, in the above-mentioned prior art, it is necessary to build a thermocouple in the mold wall for the measurement of the mold temperature. It is thus necessary to provide a hole for building-in the thermocouple and a passage for passing a lead to be connected to the thermocouple in the mold wall. This results in a complicated shape of the mold, leading to easy deformation of the mold and to a higher manufacturing cost of the mold. In addition, fitting of the thermocouple to the mold requires complicated operations and much labor is required for fitting the thermocouple and for replacing the mold.

SUMMARY OF THE INVENTION

An object of the present invention is therefore to provide a method for monitoring a breakage of a solidified shell of a cast metal strand in a mold of a horizontal type continuous casting machine, which may occur when horizontally withdrawing the cast metal strand intermittently and continuously from the mold, simply and economically at a high accuracy without applying a special modification to the mold.

In accordance with one of the features of the present invention, there is provided a method for monitoring a breakage of a solidified shell of a cast strand of metal in a mold, which may occur when horizontally withdrawing said cast strand intermittently and continuously by a plurality of cycles each comprising a pull and a push, from said mold having an outer surface and horizontally fitted by a plurality of tightening rods through the intermediary of a break ring to a feed nozzle horizontally fitted to an opening provided at the lower portion of the side wall of a tundish containing molten metal for a horizontal type continuous casting machine; which comprises:

continuously measuring the temperature of said mold while withdrawing said cast strand from said mold by said plurality of cycles, and deeming a sudden decrease in said measured temperature as representing the occurrence of a breakage of said solidified shell of said cast strand in said mold to monitor said breakage of said solidified shell of said cast strand in said mold;

characterized by:

continuously measuring strain values of said mold while withdrawing said cast strand from said mold by said plurality of cycles; and

using the thus measured strain values of said mold as functions of the temperature values of said mold, and deeming a sudden change in said measured strain values of said mold as representing the occurrence of a breakage of said solidified shell of said cast strand in said mold to monitor said breakage of said solidified shell of said cast strand in said mold.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic descriptive sectional view illustrating an instance of the connecting section between a tundish and a mold in a conventional horizontal type continuous casting machine;

Fig. 2 is a descriptive graph illustrating an instance of a conventional cycle comprising a pull and a push for horizontally withdrawing a cast metal strand intermittently and continuously from a mold;

Fig. 3(a) is a descriptive drawing illustrating the formation of a solidified shell of a cast metal strand, when horizontally withdrawing the cast strand intermittently and continuously from a mold, during a pull in a cycle comprising a pull and a push;

Fig. 3(b) is a descriptive drawing illustrating the formation of a solidified shell of a cast metal strand upon the completion of a cycle comprising a pull and a push for horizontally withdrawing the cast strand intermittently and continuously from a mold;

Fig. 3(c) is a descriptive drawing illustrating the occurrence of a breakage of a solidified shell of a cast metal strand;

Fig. 4 is a schematic descriptive sectional view illustrating an embodiment of the method of the present invention;

Fig. 5 is a graph illustrating the relation among the breakage of a solidified shell of a cast metal strand, the strain values of the mold as measured by the method of the present invention shown in Fig. 4, and the temperature values of the mold as measured by the prior art;

Fig. 6 is a schematic descriptive sectional view illustrating another embodiment of the method of the present invention; and,

Fig. 7 is a graph illustrating the relation among the breakage of a solidified shell of a cast strand, the strain values of the tightening rod as measured by the method of the present invention shown in Fig. 6, and the temperature values of the mold as measured by the prior art.

PREFERRED EMBODIMENTS OF THE INVENTION

From the above-mentioned point of view, we carried out extensive studies with a view to developing a method for monitoring a breakage of a solidified shell of a cast metal strand in a mold of a horizontal type continuous casting machine, which may occur when horizontally withdrawing the cast metal strand intermittently and continuously from the mold, simply and economically at a high accuracy without applying a special modification to the mold.

As a result, we found that, while horizontally withdrawing a cast metal strand intermittently and continuously, by a plurality of cycles each comprising a pull and a push, from a mold having an outer surface horizontally fitted, by a plurality of tightening rods, through the intermediary of a break ring, to a feed nozzle horizontally fixed to an opening provided at the lower portion of the side wall of a tundish containing a molten metal for a horizontal type continuous casting machine, the strain value of the mold has a close correlation with the temperature value of the mold during withdrawal of the cast strand, and that the strain value of the plurality of tightening rods has a close correlation with the strain value of the mold.

The present invention was made on the basis of the above-mentioned findings, and the method of the present invention for monitoring a breakage of a solidified shell of a cast metal strand which may occur when withdrawing the cast metal strand from a horizontal type continuous casting machine is described below with reference to the drawings.

Fig. 4 is a schematic descriptive sectional view illustrating an embodiment (hereinafter referred to as the "first embodiment") of the method of the present invention. In Fig. 4, 2 is a mold having a casing 9, horizontally fitted to an opening provided at the lower portion of the side wall of a tundish (not shown) for containing a molten metal, and 4 is a break ring engaging with the inlet of the mold 2. The mold 2, the casing 9, the break ring 4, and a feed nozzle (not shown) are integrally and elastically connected by a plurality of tightening rods (not shown). The outer surface 2a of the mold 2 is covered by the casing 9, and a space 12 for the circulation of cooling water for cooling the mold 2 is formed between the mold 2 and the casing 9.

Also in Fig. 4, 11 is at least one micro displacement meter for measuring the strain value of the mold 2. The at least one micro displacement meter 11 is secured to the casing 9, and a probe 11a of the at least one micro displacement meter 11 passes through the casing 9 and the tip thereof is in contact with the outer surface 2a of the mold 2. The position at which the probe 11a of the at least one micro displacement meter 11 is brought into contact with the outer surface 2a of the mold 2 should be within the range of distance of up to five times the distance of withdrawal of the cast metal strand during one of the cycles each comprising a pull and a push as measured from the inlet of the mold 2 (usually from about 5mm to about 50 mm). Preferably, the position at which the probe 11a is in contact with the outer surface 2a of the mold 2 should be within the range of distance of up to twice the distance of withdrawal of the cast metal strand during above-mentioned one cycle as measured from the inlet of the mold 2, with a view to achieving a higher measuring accuracy.

In the first embodiment shown in Fig. 4, a breakage of the solidified shell of the cast metal strand is monitored by: continuously measuring strain values of the mold 2 by means of the probe 11a of the at least one micro displacement meter 11 while withdrawing the cast metal strand from the mold 2 by the plurality of cycles each comprising a pull and a push; using the measured strain values of the mold 2 as functions of the temperature values of the mold 2; and deeming a sudden change in the measured strain values of the mold 2 as representing the occurrence of a breakage of the solidified shell of the cast metal strand in the mold 2.

In the first embodiment shown in Fig. 4, the reason why the measured strain value of the mold 2 can be used as a function of the temperature value of the mold 2 is as follows: The occurrence of a breakage of the solidified shell of the cast metal strand in the mold 2 causes a sudden decrease in the temperature of the mold 2, thus resulting in a sudden shrinkage of the mold 2. There is a very close correlation, as shown in Fig. 5, among the occurrence of a breakage of the solidified shell of the cast metal strand, the sudden decrease in the temperature of the mold 2, and the sudden shrinkage of the mold 2. It is therefore possible to monitor the occurrence of a breakage of the solidified shell of the cast metal strand by continuously measuring the strain value of the mold 2.

Fig. 5 is a graph illustrating the relation among the breakage of a solidified shell of a cast metal strand, the strain values of the mold as measured in accordance with the first embodiment of the method of the present invention shown in Fig. 4, and the temperature values of the mold as measured by the prior art. As shown in Fig. 5, when a cast metal strand is stably withdrawn from the mold 2 by a plurality of cycles each comprising a pull and a push, the measured temperature values and the measured strain values of the mold 2 proportionally vary within a certain range in agreement with the above-mentioned cycles. When the solidified shell of the cast metal strand is broken in the mold 2, on the other hand, the measured temperature values of the mold 2 suddenly decrease, and in agreement with this sudden decrease in the temperature values, the measured strain values of the mold 2 also show a sudden change.

Therefore, by continuously measuring the strain values of the mold 2 while withdrawing the cast metal strand from the mold 2 by the plurality of cycles each comprising a pull and a push, it is possible to monitor a breakage of the solidified shell of the cast metal strand in the mold 2 by deeming a sudden change in the measured strain values of the mold 2 as representing the occurrence of a breakage of the solidified shell of the cast metal strand in the mold 2.

Analysis of heat conduction and thermal stress from a high-temperature molten metal, to which the mold 2 is subjected while withdrawing a cast metal strand demonstrated a change of about several tens of μm in the strain value of the mold 2 while withdrawing the cast metal strand in a normal withdrawal. A differential transformer type displacement meter or an eddy-current type distance meter commercially available can therefore be used as the at least one micro displacement meter 11 for measuring the strain value of the mold 2.

When the mold 2 has a rectangular cross-sectional shape, at least one micro displacement meter 11 may be provided on at least a side or at least a corner of the casing 9 of the mold 2, and when the mold 2 has a circular cross-sectional shape, it suffices to provide at least one micro displacement meter 11 on the circumference of the casing 9. When a plurality of micro displacement meters 11 are used, a breakage of the solidified shell of the cast metal strand is monitored as described above by means of the average value over the values measured by the individual micro displacement meters 11.

Now, another embodiment (hereinafter referred to as the "second embodiment") of the method of the present invention is described below. Fig. 6 is a schematic descriptive sectional view illustrating the second embodiment of the method of the present invention. In Fig. 6, 2 is a mold having a casing 9, horizontally fitted to an opening provided at the lower portion of the side wall of a tundish (not shown) for containing a molten metal. A space 12 for the circulation of cooling water for cooling the mold 2 is formed between the mold 2 and the casing 9.

In Fig. 6, 3 is a feed nozzle horizontally fitted to the opening provided at the lower portion of the side wall of the tundish (not shown), and 4 is a break ring horizontally fixed between an end of the feed nozzle 3 and the inlet of the mold 2. The outer periphery of the end of the feed nozzle 3 in contact with the break ring 4 has an inclined face extending toward outside. The outer periphery of an end of the break ring 4 in contact with the mold 2 has an inclined face directed toward inside. The break ring 4 engages with the inside of the inlet of the mold 2 having an inclined face matching with the inclined face of the break ring 4.

Also in Fig. 6, 8 is an annular clamping plate having a bore at the center thereof, matching with the inclined face of the feed nozzle 3, and the inclined face of the feed nozzle 3 engaged with the bore of the clamping plate 8. The mold 3 has a flange 2b at the inlet thereof, and the casing 9 has also a flange 9a. The flange 9a of the casing 9 is fixed to the flange 2b of the mold 2.

The flange 9a of the casing 9 is secured to the clamping plate 8 by means of a plural sets of a tightening rod 5 and a nut 7 passing through a plurality of through-holes provided along the outer peripheral edges of the clamping plate 8 and the flange 9a of the casing 9. A spring 6 is provided at an end of each of the tightening rods 5.

By tightening the nuts 7, therefore, the casing 9, the mold 2, the break ring 4, and the feed nozzle 3 are integrally and elastically connected through the intermediary of the plurality of tightening rods 5 and the plurality of springs 6.

In Fig. 6, 14 is at least one strain gauge for measuring the strain value of at least one of the plurality of tightening rods 5. The at least one strain gauge 14 is attached onto the surface of at least one of the tightening rods 5 at a position between the clamping plate 8 and the flange 9a of the casing 9 of the mold 2.

In the second embodiment shown in Fig. 6, a breakage of the solidified shell of the cast metal strand is monitored by: continuously measuring strain values of the at least one tightening rod 5 by means of the at least one strain gauge 14 while withdrawing the cast metal strand from the mold 2 by a plurality of cycles each comprising a pull and a push; using the measured strain values of the at least one tightening rod 5 as functions of the strain values of the mold 2, i.e., as functions of the temperature values of the mold 2; and deeming a sudden change in the measured strain values of at least one tightening rod 5 as representing the occurrence of a breakage of the solidified shell of the cast metal strand in the mold 2.

In the second embodiment shown in Fig. 6, the reason why the measured strain value of at least one tightening rod 5 can be used as a function of the strain value of the mold 2 is as follows: The occurrence of a breakage of the solidified shell of the cast metal strand in the mold 2 causes a sudden decrease in the temperature of the mold 2 as described above, resulting in sudden shrinkage of the mold 2, and the break ring 4, the feed nozzle 3 and the clamping plate 8 displace toward the tundish 1. As a result, the strain value of the at least one tightening rod 5 changes suddenly. There is a very close correlation, as shown in Fig. 7, among the occurrence of a breakage of the solidified shell of the cast metal strand, the sudden decrease in the temperature of the mold 2, and the sudden change in the strain value of at least one tightening rod 5. It is therefore possible to monitor the occurrence of a breakage of the solidified shell of the cast metal strand by continuously measuring the strain value of at least one tightening rod 5.

Fig. 7 is a graph illustrating the relation among the breakage of a solidified shell of a cast metal strand, the strain values of at least one tightening rod as measured in accordance with the second embodiment of the method of the present invention, and the temperature values of the mold as measured by the prior art. As shown in Fig. 7, when a cast metal strand is stably withdrawn from the mold 2 by a plurality of cycles each comprising a pull and a push, the measured temperature values of the mold 2 and the measured strain values of at least one tightening rod 5 proportionally vary within a certain range in agreement with the above-mentioned cycles. When the solidified shell of the cast metal strand is broken in the mold 2, on the other hand, the measured temperature values of the mold 2 suddenly decrease, and in agreement with this sudden decrease in the temperature values, the measured strain values of at least one tightening rod 5 also show a sudden change.

Therefore, by continuously measuring the strain values of at least one tightening rod 5 while withdrawing a cast metal strand from the mold 2 by a plurality of cycles each comprising a pull and a push, it is possible to monitor a breakage of the solidified shell of the cast metal strand in the mold 2 by deeming a sudden change in the measured strain values of at least one tightening rod 5 as representing the occurrence of a breakage of the solidified shell of the cast metal strand. When a plurality of strain gauges 14 are used, a breakage of the solidified shell of the cast metal strand is monitored as described above by means of the average value over the values measured by the individual strain gauges 14.

Now, a further another embodiment (hereinafter referred to as the "third embodiment") of the method of the present invention is described below. In the third embodiment of the method of the present invention, as shown also in Fig. 6, a sleeve 13 is fitted to at least one tightening rod 5 at a position between the flange 9a of the casing 9 and the spring 6, and at least one strain gauge 14 is attached onto the surface of the sleeve 13. The strain values of the sleeve 13 are continuously measured with at least one strain gauge 14, and a breakage of the solidified shell of the cast metal strand is monitored by using the measured strain values of the sleeve 13 as functions of the strain values of at least one tightening rod 5, i.e., as functions of the temperature values of the mold 2, and deeming a sudden change in the measured strain values of the sleeve 13 as representing the occurrence of a breakage of the solidified shell of the cast metal strand in the mold 2.

In the third embodiment shown in Fig. 6, the reason why the measured strain value of the sleeve 13 can be used as a function of the strain value of the at least one tightening rod 5 is as follows: When a breakage of the solidified shell of the cast metal strand occurs in the mold 2, the strain value of the at least one tightening rod 5 shows a sudden change as ~~described above, and~~ at the same time, there is a sudden shrinkage of the sleeve 13. There is a very close correlation, as shown in Fig. 7, among the shrinkage of the solidified shell of the cast metal strand, the sudden decrease in the temperature of the mold 2, and the sudden shrinkage of the sleeve 13. By continuously measuring changes in the strain values of the sleeve 13 engaging with the at least one tightening rod 5, therefore, it is possible to monitor a breakage of the solidified shell of the cast metal strand.

The temperature of at least one tightening rod 5 and the sleeve 13 engaging with at least one tightening rod 5 increases under the effect of the heat of the cast metal strand in the mold 2, and this increase in temperature is of the order of 150°C on the maximum according to the results of actual measurements. Therefore, a commercially available high-temperature strain gauge (capable of measuring temperatures of up to about 400°C) may be used as the at least one strain gauge to be attached to at least one tightening rod 5 or to the sleeve 13, and if the at least one tightening rod 5 or the sleeve 13 is air-cooled, a commercially available ambient-temperature strain gauge may be employed.

The number of strain gauges 14, for measuring the strain value of the tightening rod 5, to be attached to at least one tightening rod 5 depends upon the diameter and the length of the tightening rod 5. The number of strain gauges 14, for measuring the strain value of the sleeve 13, to be attached to the aleeve 13 engaging with at least one tightening rod 5, depends upon the diameter and the length of the sleeve 13.

The strain produced in the at least one tightening rod 5 or the sleeve 13 is within the range of elasticity limit of the at least one tightening rod 5 or the sleeve 13. It is therefore possible to continuously measure the strain value produced in the at least one tightening rod 5 or the sleeve 13 with at least one strain gauge 14 attached to one tightening rod 5 or the sleeve 13. When a plurality of strain gauges 14 are used, the occurrence of a breakage of the solidified shell of the cast metal strand is monitored as described above by means of the average value over the measured strain values by the individual strain gauges.

Now, the method of the present invention is described below with reference to examples.

Example 1

A breakage of a solidified shell of a cast strand of ordinary steel having sides of 115 mm each and a rectangular cross-section in a mold, which might occur when horizontally withdrawing the cast strand intermittently and continuously from the mold of a horizontal type continuous casting machine was monitored in accordance with the first embodiment of the method of the present invention described above with reference to Fig. 4, by continuously measuring strain values of the mold 2.

A differential transformer type displacement meter was employed as the micro displacement meter 11 for measuring the strain values of the mold 2. The differential transformer type displacement meter was provided at a position corresponding to a distance twice the distance of withdrawal of the cast strand in a cycle comprising a pull and a push starting from the inlet of the mold 2, and secured to the casing 9 so that the probe 11a came into contact with the outer surface 2a of a side of the mold 2 at the center thereof. The strain values of the mold 2 were continuously measured by means of the above-mentioned differential transformer type displacement meter. For comparison purposes, on the other hand, a thermocouple was built in the wall of the mold 2 near the position at which a solidified shell was to be first formed in accordance with the prior art to continuously measure the temperatures of the mold 2.

As a result, it was possible to certainly monitor, meter used for measuring the strain values of the mold 2 was secured to the casing 9 of the mold 2, it was not necessary to disengage and attach it again in replacing the mold 2, and no problem was posed regarding the durability thereof.

Example 2

A breakage of a solidified shell of a cast strand of ordinary steel having sides of 115 mm each and a rectangular cross-section in a mold, which might occur when horizontally withdrawing the cast strand intermittently and continuously from the mold of a horizontal type continuous casting machine was monitored in accordance with the second embodiment of the method of the present invention described above with reference to Fig. 6, by continuously measuring strain values of the tightening rods 5.

One strain gauge 14 was attached to each of four tightening rods 5 for securing the flange 9a of the casing 9 to the clamping plate 8. The strain values of each of the four tightening rods 5 were continuously measured with these strain gauges 14 to derive an average value. Rods having a strain sensitivity of 2×10^{-3} against a lod of 1 ton were employed as the four tightening rods 5. For comparison purposes, on the other hand, a thermocouple was built in the wall of the mold 2 near the position at as shown in Fig. 5, the occurrence of a breakage of the solidified shell of the cast strand in the mold 2 from a sudden change in the measured strain values of the mold 2. The sudden change in the measured strain values of the mold 2 caused by the breakage of the solidified shell agreed with a sudden decrease in the temperature values of the mold 2 as measured with the thermocouple.

When the measured strain values of the mold 2 suddenly changed, withdrawal of the cast strand from the mold 2 was temporarily discontinued to cool and solidify molten metal having penetrated into the broken portion of the solidified shell of the cast strand to weld the broken portion. Then, by resuming the withdrawal of the cast strand from the mold 2, the cast strand could successfully be withdrawn from the mold 2 without the occurrence of a breakout.

In this example, the occurrence of a breakage of the solidified shell of the cast strand in the mold 2 was monitored by the above-mentioned method while continuously casting molten steel in a quantity of 93 50-ton ladles, and the occurrence of the breakage of the solidified shell of the cast strand could be properly detected at a very high accuracy.

Since the differential transformer type displacement which a solidified shell was to be first formed in accordance with the prior art to continuously measure the temperatures of the mold 2.

As a result, it was possible to certainly monitor, as shown in Fig. 7, the occurrence of a breakage of the solidified shell of the cast strand in the mold 2 from a sudden change in the average value over the measured strain values of the four tightening rods 5. The sudden change in the average value over the measured strain values of the four tightening rods 5 caused by the breakage of the solidified shell agreed with a sudden decrease in the temperature values of the mold 2 as measured with the thermocouple.

When the average value over the measured strain values of the four tightening rods 5 suddenly changed, withdrawal of the cast strand from the mold 2 was temporarily discontinued to cool and solidify molten metal having penetrated into the broken portion of the solidified shell of the cast strand to weld the broken portion. Then, by resuming the withdrawal of the cast strand from the mold 2, the cast strand could successfully be withdrawn from the mold 2 without the occurrence of a breakout.

In this example, the occurrence of a breakage of the solidified shell of the cast strand in the mold 2 was monitored by the above-mentioned method while continuously casting molten steel in a quantity of 67 50-ton ladles, and the occurrence of the breakage of the solidified shell of the cast strand could be properly detected at a very high accuracy.

Example 3

A breakage of a solidified shell of a cast strand of ordinary steel having sides of 115 mm each and a rectangular cross-section in a mold, which might occur when horizontally withdrawing the cast strand intermittently and continuously from the mold of a horizontal type continuous casting machine was monitored in accordance with the third embodiment of the method of the present invention described above with reference to Fig. 6, by continuously measuring the strain values of the sleeve 13 engaging with one of the tightening rods 5.

One strain gauge 14 was attached to the surface of the metal sleeve 13 engaging with one of the four tightening rods 5 for securing the flange 9a of the casing 9 to the clamping plate 8 at a position between the flange 9a of the casing 9 and the spring 6. The strain values of the sleeve 13 were continuously measured with this strain gauge 14. For comparison purposes, on the other hand, a thermocouple was built in the wall of the mold 2 near the position at which a solidified shell was to be first formed in accordance with the prior art to continuously measure the temperatures of the mold 2.

As a result, it was possible to certainly monitor, as in Example 2, the occurrence of a breakage of the solidified shell of the cast strand in the mold 2 from a sudden change in the measured strain values of the sleeve 13. The sudden change in the measured strain values of the sleeve 13 caused by the breakage of the solidified shell agreed with a sudden decrease in the temperature values of the mold 2 as measured with the thermocouple.

Since, in Example 3, the strain gauge 14 was attached to the sleeve 13 engaging with the tightening rod 5, replacement of the tightening rods 5 could be effected without regard to the strain gauge 14, and the measuring sensitivity could arbitrarily set by altering the thickness or the length of the sleeve 13.

According to the method of the present invention, as described above in detail, it is possible to monitor a breakage of a solidified shell of a cast metal strand in a mold of a horizontal type continuous casting machine, which may occur when horizontally withdrawing the cast metal strand intermittently and continuously from the mold, simply and economically at a high accuracy without applying a special modification to the mold, thus providing many industrially useful effects.

WHAT IS CLAIMED IS:

1. A method for monitoring a breakage of a solidified shell of a cast strand of metal in a mold, which may occur when horizontally withdrawing said cast strand intermittently and continuously by a plurality of cycles each comprising a pull and a push, from said mold having an outer surface and horizontally fitted by a plurality of tightening rods through the intermediary of a break ring to a feed nozzle horizontally fitted to an opening provided at the lower portion of the side wall of a tundish containing molten metal for a horizontal type continuous casting machine; which comprises:

continuously measuring the temperature of said mold while withdrawing said cast strand from said mold by said plurality of cycles, and deeming a sudden decrease in said measured temperature as representing the occurrence of a breakage of said solidified shell of said cast strand in said mold to monitor said breakage of said solidified shell of said cast strand in said mold;

characterized by:

continuously measuring strain values of said mold while withdrawing said cast strand from said mold by said plurality of cycles; and

using the thus measured strain values of said mold as functions of the temperature values of said mold, and deeming a sudden change in said measured strain values of said mold as representing the occurrence of a breakage of said solidified shell of said cast strand in said mold to monitor said breakage of said solidified shell of said cast strand in said mold.

2. The method as claimed in Claim 1, characterized by:

bringing a probe of at least one micro displacement meter into contact with said outer surface of said mold within the range of distance of up to five times the distance of withdrawal of said cast strand during one of said cycles each comprising a pull and a push, as measured from the inlet of said mold, to continuously measure said strain values of said mold.

3. The method as claimed in Claim 2, characterized by:

bringing said probe of said at least one micro displacement meter into contact with said outer surface of said mold within the range of distance of up to twice the distance of withdrawal of said cast strand during said one cycle as measured from the inlet of said mold.

4. The method as claimed in Claim 1, characterized by:

attaching at least one strain gauge onto the surface of at least one of said plurality of tightening rods to continuously measure strain values of said at least one of said plurality of tightening rods; and

using the thus measured strain values of said at least one of said plurality of tightening rods as functions of said strain values of said mold, and deeming a sudden change in said measured strain values of said at least one of said plurality of tightening rods as representing the occurrence of a breakage of said solidified shell of said cast strand in said mold to monitor said breakage of said solidified shell of said cast strand in said mold.

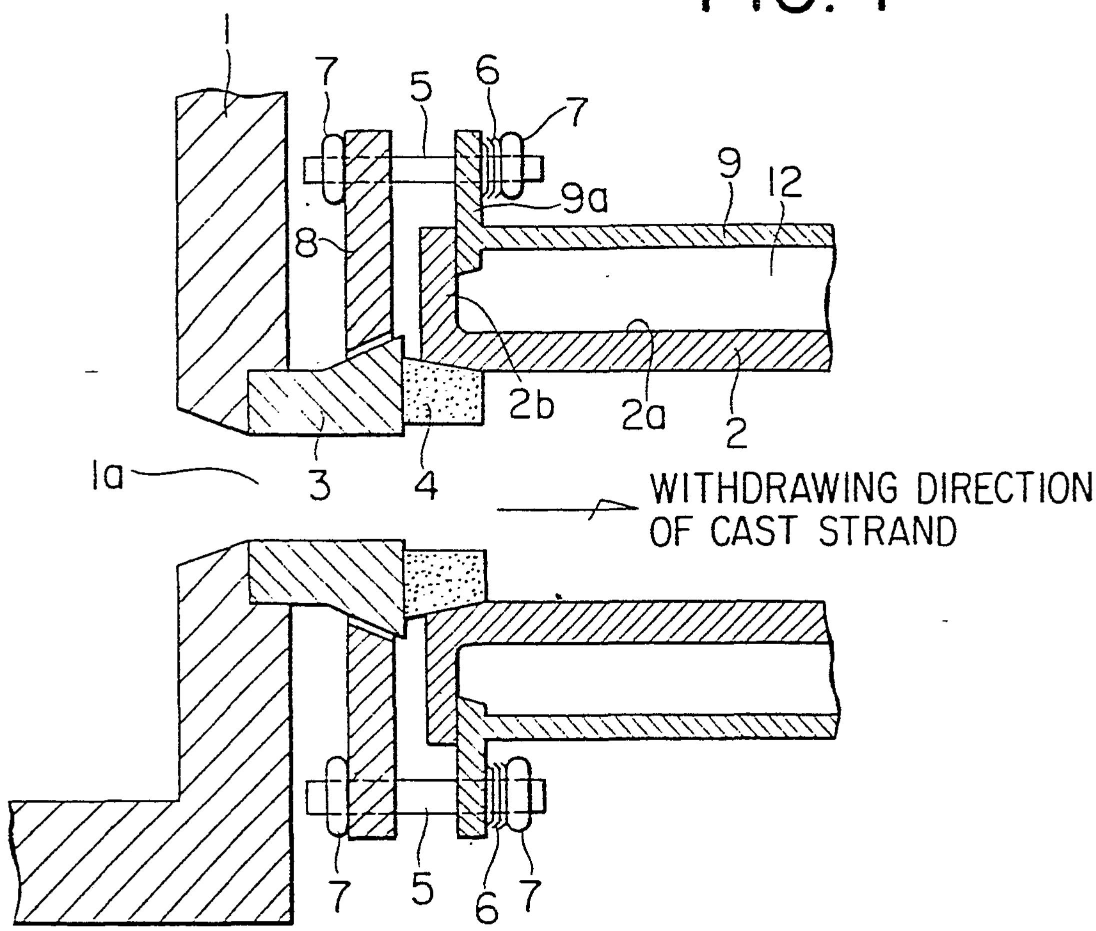
5. The method as claimed in Claim 4, characterized by:

fitting a sleeve to at least one of said plurality of tightening rods;

attaching at least one strain gauge onto the surface of said sleeve to continuously measure strain values of said sleeve; and

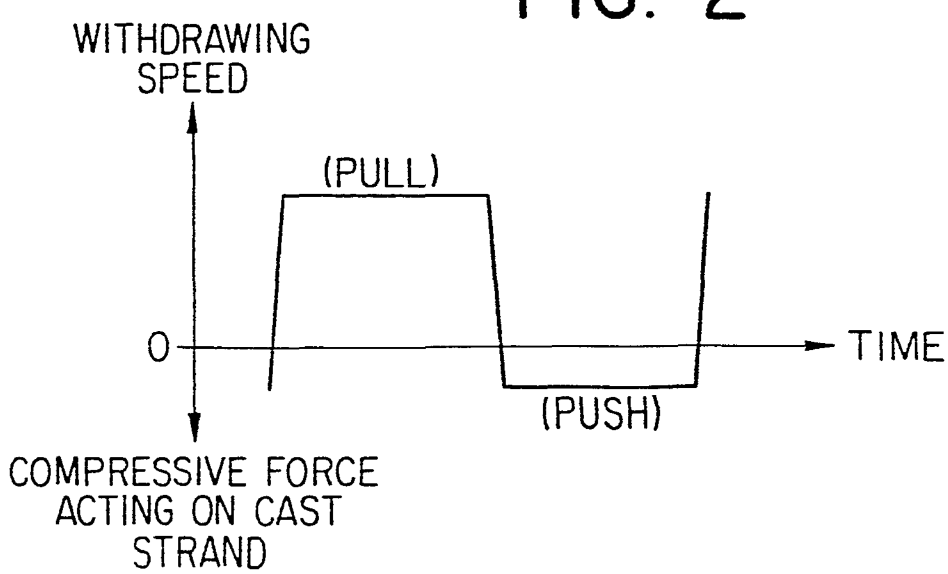
using the thus measured strain values of said sleeve as functions of said strain values of said at least one of said plurality ~~of tightening rods, and~~ deeming a sudden change in said measured strain values of said sleeve as representing the occurrence of a breakage of said solidified shell of said cast strand in said mold to monitor said breakage of said solidified shell of said cast strand in said mold.

FIG. 1



1
7
5
6
7
9
12
9a
8
2b
2a
2
1a
3
4
WITHDRAWING DIRECTION OF CAST STRAND
7
5
6
7

FIG. 2



WITHDRAWING SPEED
(PULL)
0
TIME
(PUSH)
COMPRESSIVE FORCE ACTING ON CAST STRAND

FIG. 3 (a)

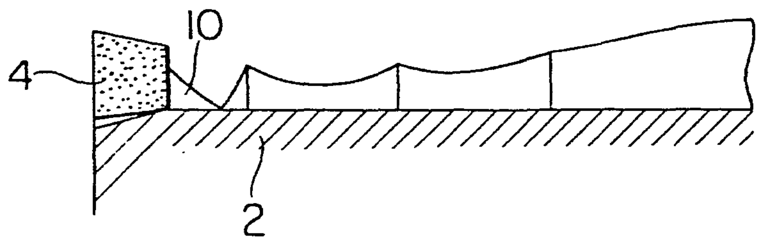


FIG. 3 (b)

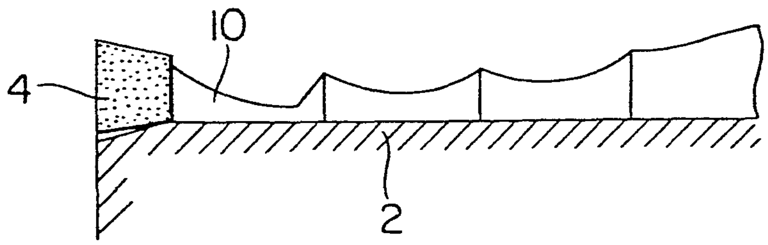
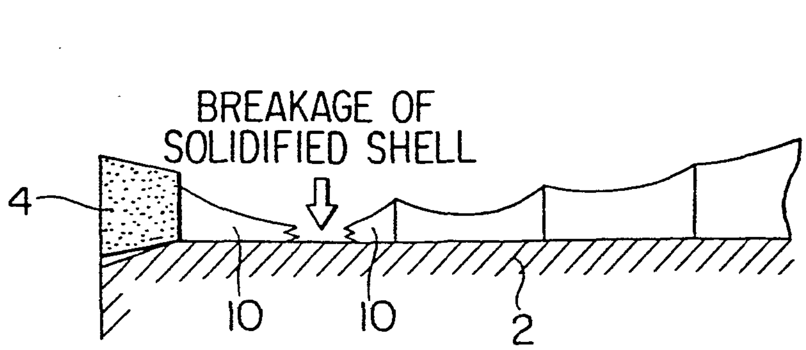
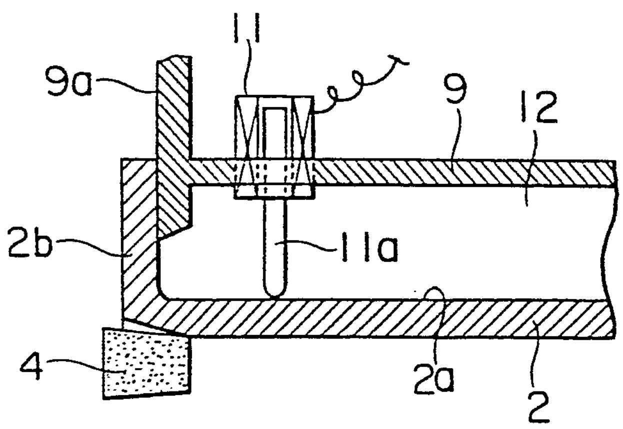


FIG. 3 (c)

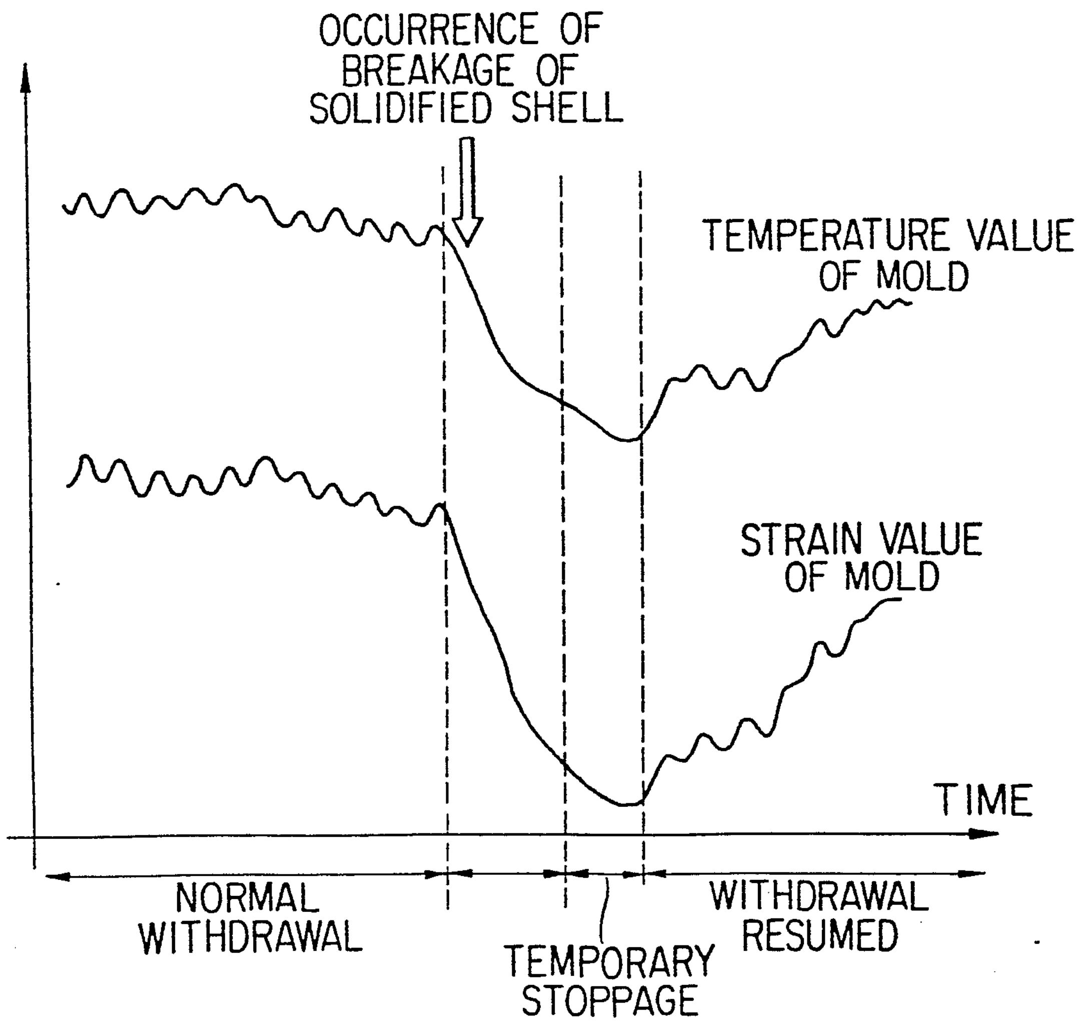




9a
11
9
12
2b
11a
4
2a
2

FIG. 4

FIG. 5



OCCURRENCE OF BREAKAGE OF SOLIDIFIED SHELL
TEMPERATURE VALUE OF MOLD
STRAIN VALUE OF MOLD
TIME
NORMAL WITHDRAWAL
TEMPORARY STOPPAGE
WITHDRAWAL RESUMED

FIG. 6

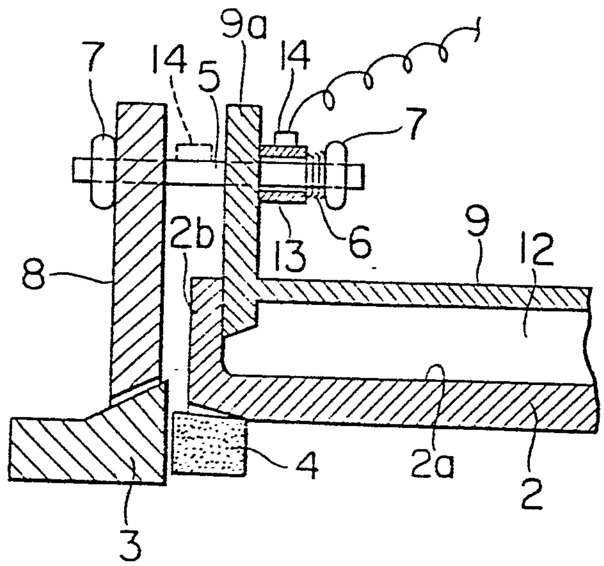
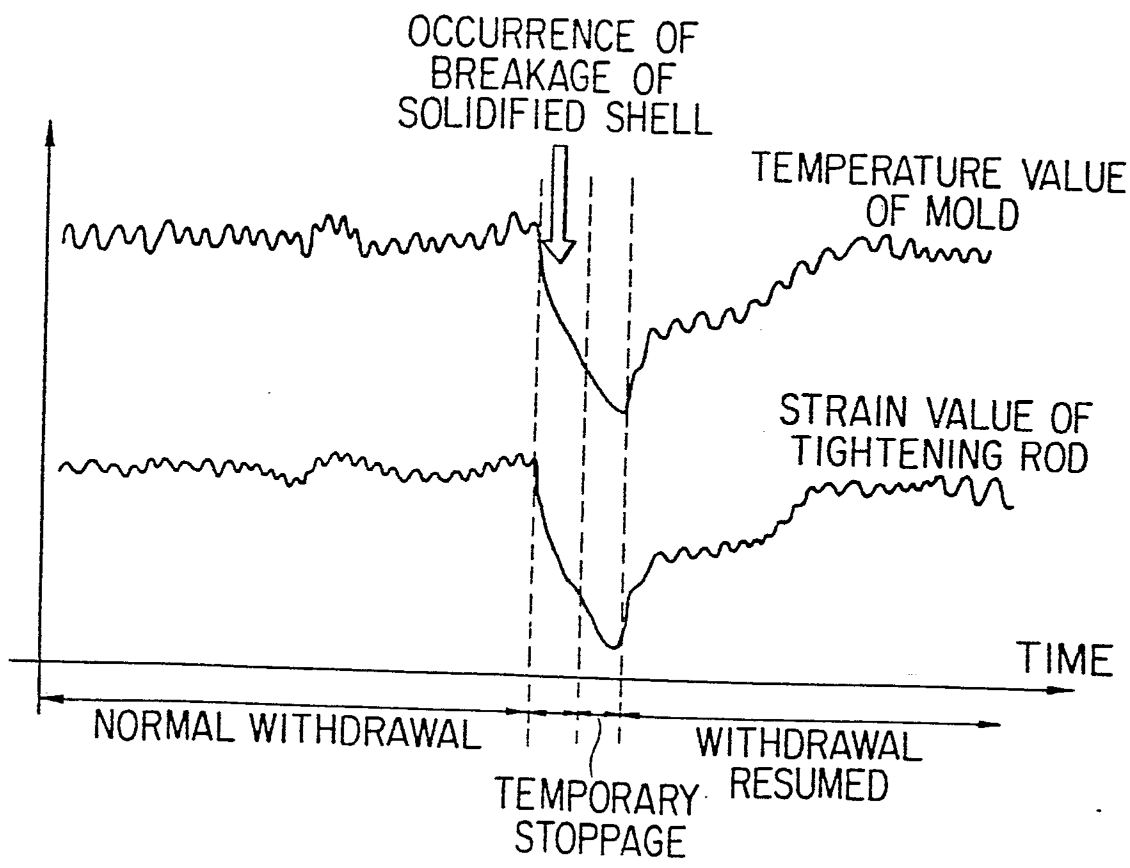

7
14
5
9a
14
7
8
2b
13
6
9
12
2a
4
2
3

FIG. 7


OCCURRENCE OF BREAKAGE OF SOLIDIFIED SHELL
TEMPERATURE VALUE OF MOLD
STRAIN VALUE OF TIGHTENING ROD
TIME
NORMAL WITHDRAWAL
TEMPORARY STOPPAGE
WITHDRAWAL RESUMED

INTERNATIONAL SEARCH REPORT

International Application No PCT/JP83/00154

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{3} B22D 11/16, B22D 11/04

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
I P C	B22D 11/16, B22D 11/04

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

Jitsuyo Shinan Koho	1971 - 1983
Kokai Jitsuyo Shinan Koho	1971 - 1983

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category*	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	JP,B1, 49-26812 (General Motors Corp.) 12. July. 1974 (12. 7. 74) & GB,A, 1307423 & FR,B2, 2077534 & DE, C3, 2058051	1 - 5
A	JP,A, 53-58928 (Nippon Steel Corp.), 27. May 1978 (27. 5. 78)	1 - 5
P	JP,A, 57-97856 (Kobe Steel, Ltd.), 17. June 1982 (17. 6. 82)	1 - 5

* Special categories of cited documents: [15]

"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

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"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

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
July 27, 1983 (27. 07. 83)	August 8, 1983 (08. 08. 83)
International Searching Authority [1]	**Signature of Authorized Officer** [20]
Japanese Patent Office	

BAD ORIGINAL

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International Application No. PCT/JP83/00154

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- "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
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