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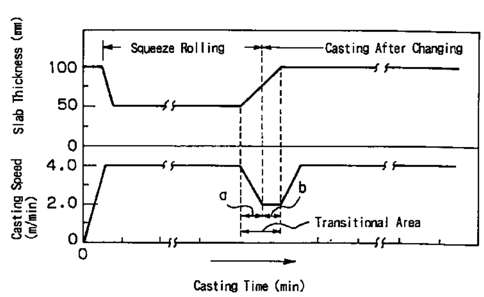
(54) METHOD OF CONTINUOUSLY CASTING THIN CAST PIECES

(57) Object: to provide a method of continuously casting thin cast pieces. Constitution: a method of unsolidified rolling continuous casting, by which unsolidified cast pieces are subjected to rolling in a roller apron zone to produce thin cast pieces, and in which thin cast pieces are cast in the following steps 1 and 2: 1. a steady casting speed is temporarily decreased to a speed, at which thin cast pieces after rolling become completely solidified in an unsolidified rolling zone, and 2. after a thickness of a thin cast piece having been subjected to rolling is restored to an original thickness of the cast piece before the start of rolling, a casting speed is again increased to the original steady casting speed to release a rolling force at the time of rolling.

Fig. 2



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Description

The present invention relates to a process for continuously casting thin slabs, and particularly to a process for continuously casting thin slabs and carrying out rolling of the slabs before they are completely solidified, in which the rolling reduction force can be released during the rolling so that thin slabs free of internal defect with varied thicknesses can be produced.

A typical process for making thin plates comprises continuously casting slabs, cooling the slabs, and then subjecting the once-cooled slabs to hot rolling. According to this process, however, it is necessary to heat the slabs which have been air-cooled after casting, and this process is disadvantageous with respect to energy consumption.

Recently, in view of the advantage that it can reduce energy costs markedly, a direct rolling process is under development. The direct rolling process is a process for directly supplying cast slabs from a continuous casting machine to a hot rolling mill without intentional cooling. When thin cast slabs are used, it is possible to omit rough hot rolling steps from the direct rolling process. Currently, many attempts have been made to develop a new and practical continuous casting process for such thin slabs.

The direct rolling process using such thin slabs is advantageous because it is possible to omit rough hot rolling steps and because it is possible to achieve a less energy consuming, simple process as a whole for making steels in a more efficient manner.

A recently-proposed process for producing thin slabs is a process for casting slabs with a mold having the same thickness as is conventional, but not with a mold having a reduced thickness, and carrying out rolling of the cast slab while a central portion of the slab is unsolidified to reduce the thickness. This process for carrying out roll reduction before the slab is solidified is referred to as "squeeze reduction".

It is now required that the thickness of the cast slab itself be changed during casting depending on the types of steel, production lots, and the sheet thickness required in the succeeding steps. For this purpose, a continuous casting operation is carried out so as to achieve not only squeeze reduction of an unsolidified cast slab to reduce the thickness of the slab, but also the release of the roll reduction force to increase or change the thickness of the cast slab. However, in such a case the presence of a transitional area from a slab having one thickness to another slab having another thickness, i.e., an unstable area, is unavoidable.

Usually, in case of squeeze reduction, since the mold has a small thickness, an immersion nozzle must employ a rather thin refractory wall compared with conventional ones. Breaking of the immersion nozzle due to corrosive damage to the refractory easily occurs. Thus, since the service life of the nozzle is short, the number of strands which can be cast simultaneously is at most 3. In this respect, continuous casting of 7 or 8 strands is possible for conventional processes. Since the number of strands is limited, therefore, it is critical how to reduce the unstable area in order to increase the yield of the product.

In addition, if internal defects are once formed in a cast slab upon release of the roll reduction force during casting, portions of the slab where such internal defects are present must be rejected as unstable areas. Thus, there is a great need for the development of a casting method which can successfully prevent occurrence of internal defects in cast slabs at the time when the roll reduction force is released in order to increase the yield of the product.

Namely, in order to further improve the yield of the product, it is also advantageous not only to reduce the length of the unstable area upon release of the roll reduction force, but also to ensure the quality of the slab.

However, the prior art does not suggest anything at all about how to reduce the length of the unstable area, or how to prevent formation of internal defects in the slab at the time of release of the roll reduction force during squeeze reduction.

An object, therefore, of the present invention is to provide a process for continuously casting thin slabs and carrying out squeeze reduction of the slabs, in which the roll reduction force can be released during casting so as to change the thickness of the slab while preventing formation of internal defects.

Another object of the present invention is to provide a process for continuously casting thin slabs and carrying out squeeze reduction of the slabs, in which the roll reduction force can be released to decrease the length of an unstable area of the slab to be as short as possible and to change the thickness of the slab during casting while preventing formation of internal defects.

It is to be noted, however, that it is impossible to reduce the length of an unstable area and to ensure quality of a slab merely by adjusting the roll gap at the time of release of the roll reduction force during casting. Take for example the case in which the roll reduction force is released while casting is carried out at a constant casting speed. An unsolidified slab, i.e., a slab which has not yet been solidified completely, if it is free from roll reduction pressure, swells again to result in bulging due to the static pressure of molten steel. The bulging will cause a marked segregation in a central portion of the slab, as well as internal cracking, resulting in a further degradation in quality of the unstable area.

If the operation to release the roll reduction force is called a "release operation", the release operation starts when the changing point of the slab passes the final reduction roll. After this point, the roll reduction force is released until a predetermined slab thickness is obtained. Regarding these features, the inventors of the present invention found the following.

First of all, the inventors noted that even when the thickness is increased by releasing the roll reduction force during squeeze reduction, bulging does not occur under constant cooling conditions if the solidifying front, i.e., the position where the slab is solidified completely, is within the squeeze reduction zone where an unsolidified portion always remains. Thus, the inventors found that if the following conditions are satisfied when the thickness of the slab is changed, it is possible to change the thickness of the slab successfully while preventing formation of internal defects, thereby completing the present invention.

(i) The casting speed is reduced, for example, from a stable normal casting speed to another casting speed equal to or lower than the casting speed at which the thin slab can be solidified completely within the squeeze reduction zone, provided that the thickness of the slab has been reduced to a target thickness under given cooling conditions. Under these cooling conditions, the roll reduction force is released during squeeze reduction while the solidifying front is kept at a point upstream from the end of the roll reduction zone.

(ii) After the target thickness of the slab is achieved, the casting speed is then increased to the stable normal casting speed for the target thickness of the slab.

As a result, the present invention is, in a broad sense, a continuous casting and squeeze reduction process for producing thin slabs in which cast slabs having an unsolidified portion are reduced in thickness in the roll reduction zone, characterized in that while the solidifying front is kept at a point upstream of the roll reduction finishing area, for example, by controlling the casting speed, the roll reduction force is released during squeeze reduction to change the thickness of the slab to a target thickness.

In another aspect, the present invention is a continuous casting and squeeze reduction process for producing thin slabs in which cast slabs having an unsolidified portion are reduced in thickness in the roll reduction zone, characterized in that the casting speed is changed to a casting speed which is lower or higher than the casting speed at which the cast slab having a target thickness after changing the thickness can be completely solidified within the squeeze reduction zone, then while the solidifying front is kept at a point upstream of the roll reduction finishing area, simultaneously, or during or after changing the thickness, the roll reduction force is released until a target thickness of the slab is achieved, and the casting speed is changed to the normal casting speed for the target thickness of the slab.

According to a preferred embodiment of the present invention, it is desirable that the changing in the casting speed be started at the same time or prior to the time when the changing point of the cast slab passes the roll reduction finishing area.

Fig. 1 is a vertical side view in section of a continuous casting machine employed for carrying out the process of the present invention.

Fig. 2 is a graph showing relationships between the thickness of a cast slab and the casting speed, which are obtained when the thickness of slab is changed in accordance with a process of the present invention.

Fig. 3 is a graph similar to that of Fig. 2, showing the change of thickness of cast slabs in a comparative example.

Fig. 4 is a longitudinal side view of the shape of a cast slab during process in which the roll reduction force is released in accordance with the present invention.

Fig. 5 is a longitudinal side view of the shape of a cast slab during the release of the roll reduction force in a comparative example.

Fig. 6 is a longitudinal vertical view in section of a cast slab showing the occurrence of internal defects in the slab during the release of the roll reduction force in a comparative example.

Fig. 7 is a graph showing the results of the working examples.

Fig. 1 is a schematic illustration of the structure of a continuous casting machine (hereunder referred to merely as "machine") which is preferably used for carrying out the process of the present invention.

In the figure, the machine comprises a mold 1, a roller apron zone 2, and pinch roll zone 3. The machine may be any type of machine, e.g., a conventional curved type or a VB type. The roller apron zone 2 comprises a series of groups of rolls 4, some of which may be groups of driving rolls 4'. In the roller apron zone 2 is provided a squeeze reduction zone 7 which comprises a plurality of segments 6, each having rolls 4 and/or driving rolls 4' provided with a reduction cylinder 5.

The squeeze reduction zone 7 located within the roller apron zone 2 comprises a total of 5 segments, as shown in the drawings, and is located within about 6 m from a meniscus 10 of molten steel 9 in the mold 1.

Mold 1 measures about 90 - 150 mm in thickness and about 1000 - 1800 mm in width. Cast slabs having these dimensions are reduced to a thickness of about 30 - 70 mm by squeeze reduction. A preferred squeeze reduction pattern for the machine mentioned above, therefore, is such that a reduction of about 5 - 35 mm is scheduled for each of the segments.

A preferred normal casting speed ranges from 3.0 m/min to 5.0 m/min. Cooling conditions can be adjusted so that such a casting speed can be ensured. The preferred casting speed varies depending on the thickness of the slab, and hereunder it will sometimes be referred to simply as a "predetermined casting speed".

However, depending on the production schedule, it is sometimes necessary to continue casting by releasing a roll reduction force to restore the slab to its original thickness of 100 mm from a thickness of 50 mm during casting based on the relationship between the type of steel and the casting speed.

If only the roll reduction force is released without a reduction in the casting speed, although there will be no re-swelling due to bulging upon release of the roll reduction force in an area where the solidified shells have been completely bonded with each other by roll reduction, there will be a re-swelling portion due to bulging upon release of the roll reduction force in an area where solidification has not yet been completed.

Namely, if the roll reduction force is released immediately in an area between the point where the roll reduction starts, the solidifying front moves downstream from the roll reduction finishing area within the roll reduction zone, and the slab swells due to bulging, causing possible marked deterioration in internal quality of the slab, such as formation of internal cracking and a degradation in central segregation.

It is advisable that the release of the roll reduction force not be carried out immediately after the changing point of the thin slab passes the roll reduction zone, but that the release of the roll reduction force be carried out after or at the same time that the casting speed is lowered to a speed at which the thin slab after roll reduction can be completely solidified within the squeeze reduction zone. Thus, it is possible to gradually increase the slab thickness to restore its original thickness while successfully avoiding occurrence of bulging which inevitably occurs in a transitional period in the release of the roll reduction force. According to this process of releasing the roll reduction force, it is possible to produce cast slabs which are free of deterioration of internal quality even in a transitional area during the thickness changing period so that continuous casting can be continued efficiently without a reduction in yield.

The process of the present invention will be described in further detail with reference to Fig. 2. Fig. 2 is an illustration showing relationships between the thickness of a cast slab and the casting speed, which are obtained when the thickness of a slab is changed in accordance with a process of the present invention.

The following description is based on the case in which squeeze reduction is carried out under usual conditions so as to reduce the thickness of slabs from 100 mm to 50 mm, and then the thickness is returned to 100 mm. The casting speed is changed at the same time when the release of the roll reduction force is carried out, i.e., when the changing point of the slab passes the roll reduction finishing area of the roll reduction zone.

In the beginning, the casting of a slab 100 mm thick is started and continued at a given casting speed of 4.0 m/min, and squeeze reduction is carried out to reduce the thickness of the slab to 50 mm. It is assumed that it is necessary to change the thickness of the slab from 50 mm to 100 mm because of a requirement from a production schedule for example. A shift of operating conditions at this time is started when the changing point of the slab passes the roll reduction finishing area of the squeeze reduction zone. Namely, the casting speed is continuously reduced to 2.0 m/min, and simultaneously the roll reduction force is also continuously released. The target casting speed mentioned above is equal to or lower than the casting speed at which a cast slab having a target thickness, 100 mm in this example, is completely solidified within the roll reduction zone. Thus, the casting speed can be varied depending on a target thickness of the slab. In other words, although the solidified front moves upstream or downstream of the roll reduction zone depending on a lowering of the casting speed and on a release of the roll reduction force, so long as the solidifying front is essentially located upstream of the roll reduction finishing area within the squeeze reduction zone, the casting speed as well as the rate of releasing the roll reduction force are not limited to any specific ones.

The rate of decreasing the casting speed is not limited to a specific level, and it is preferable that the casting speed be lowered as quickly as the machine permits from the viewpoint of avoiding the occurrence of unstable states as completely as possible. In Figure 2, the length "a" means the length of time required to reduce the casting speed to a target speed.

After the casting speed is lowered to a given casting speed, the casting is continued at the given casting speed. On the other hand, during this period of time, the release of the roll reduction force is also continued. After the roll reduction force is reduced to a target level, i.e., after a target thickness of the cast slab is achieved, then the casting speed begins to return to the normal casting speed. The length "b" up to this point of time means the length of time required for the solidifying front located upstream from the roll reduction finishing area of the roll reduction zone to return to the roll reduction finishing zone.

Namely, the solidifying front which is once moved upstream of the roll reduction finishing area due to a reduction in the casting speed continues moving gradually to downstream of the roll reduction finishing area as the thickness of the slab increases. The solidifying front returns to the roll reduction finishing area after time b elapses. After this point of time, the casting speed can be increased by adjusting cooling conditions while the solidifying front is kept at this position. Alternatively, the solidifying front may be situated upstream of the roll reduction finishing area after the elapse of time b, and the solidifying front may be returned to the roll reduction finishing area by increasing the casting speed.

The length (a + b) in Figure 2 corresponds to the length of an unstable area, and it is highly advantageous to decrease this length as much as possible to further improve the yield. In order to achieve this purpose, according to an embodiment of the present invention, the length "a" or "b" is decreased as much as possible.

Thus, according to another embodiment of the present invention, the casting speed may start to change prior to the time when the changing point of the slab passes the roll reduction finishing area. This embodiment will be described below.

The point of time when the casting speed is changed, i.e., the starting point of a change in thickness is determined on the basis of the point in time when the changing point passes the roll reduction finishing area. A target casting speed to be reached is previously determined to be 2.0 m/min at which speed, in this case, a cast slab 100 mm thick can be solidified completely at the roll reduction finishing area.

Next, the point of time at which the thickness of a slab is required to be changed to 100 mm under usual conditions due to the requirements of a production schedule is determined on the basis of the roll reduction finishing area.

Further, the time required to reduce the casting speed from 4.0 m/min to 2.0 m/min is determined.

In the above-mentioned case, for example, if the deceleration rate for the casting speed is 2.0 m/min^2, the casting speed can be lowered to 2.0 m/min in 1 minute, and at least one minute is necessary to reduce the casting speed from 4.0 m/min to 2.0 m/min. Three minutes are necessary for the casting speed to return to a given stable casting speed before the changing point of the slab passes the roll reduction finishing area which is located 6 m downstream from the meniscus in the mold. Thus, the casting speed may start to be lowered from the point 4 minutes upstream from the point of time or location when or where the changing point of the slab passes the roll reduction finishing area.

According to the present invention, therefore, in order to change the thickness of a cast slab, first of all, a stable casting speed is changed to a casting speed lower than the speed at which a thin slab is completely solidified within the squeeze reduction zone. Provided that the target thickness of a thin slab is 100 mm and the distance from the molten steel meniscus in the mold to the roll reduction finishing area is 6 m, the above-mentioned casting speed is one at which the thickness of the solidified shell is 50 mm at the point of the roll reduction finishing area. Thus, in order to achieve complete solidification, a preferred casting speed is determined depending on the thickness of the mold and the length of the squeeze reduction zone. In general, a preferred casting speed is in the range of 1.0 - 2.0 m/min.

In addition, the rate at which the casting speed is changed, i.e., an acceleration or deceleration rate preferably is in the range of 1.0 - 4.0 m/min^2.

Since the casting is carried out continuously, the casting speed in the squeeze reduction zone is also decreased when the casting speed in the mold is decreased. An unsolidified slab must be subjected to squeeze reduction when the thickness of a solidified shell of the unsolidified slab has increased. The roll reduction force, however, is not large enough to enable so-called rolling to be achieved. As the thickness of the solidified shell increases, therefore, an increment of the solidified shell thickness cannot be diminished, and the thickness of the slab inevitably increases to two times the solidified shell thickness.

In the embodiment mentioned above, a cast slab 100 mm thick is subjected to squeeze reduction to form a slab 50 mm thick, and then the thickness of the slab is returned to 100 mm. Even if the slab is returned to a thickness of 70 mm or 80 mm, the same procedures as mentioned above can be applied so as to restore the thickness, though it is necessary not only to install a position sensor in reduction rolls, but also to control the casting speed and roll gaps so as to change the thickness of the slab to a target value.

Next, working examples of the present invention together with its effects will be described in detail.

Examples

(Example 1)

Medium carbon, Al-killed steel having the steel composition shown in Table 1 was cast at a normal casting speed of 5.0 m/min with a machine of the curved type shown in Figure 1. The mold was 100 mm thick and 1500 mm wide. The cast slab was further subjected to squeeze reduction to produce a thin slab having target dimensions of 50 mm thick and 1500 mm wide. In the course of the above-mentioned continuous casting, the thickness of the slab was returned to 100 mm. The casting speed at which a cast slab was completely solidified before it passed the roll reduction finishing area was 1.3 m/min for a slab thickness of 100 mm.

In this example, under normal conditions, a cast slab having an unsolidified portion in the slab was subjected to squeeze reduction to reduce the thickness to 50 mm. The roll reduction zone was located in an area 3 m long between the first segment and the fifth segment in the roller apron zone of the machine. The roll reduction finishing area was located 4 m down from the molten steel meniscus in the mold. The roll reduction was carried out at a uniform reduction rate with a reduction of 10 mm for each of the segments.

Table 1 (%by weight)

C	Si	Mn	P	S	Al	Fe
0.12	0.045	0.80	0.015	0.008	0.045	bal.

In this example, a 2-strand machine was used. A process for restoring the cast slab thickness through squeeze reduction in accordance with the present invention, as shown in Fig. 2, was carried out by using the first strand casting machine. In this case, since the casting speed at which a slab was completely solidified before it passed the roll reduction finishing area was 1.3 m/min, the casting speed was once reduced to 1.3 m/min and the roll reduction force was simultaneously released. After the thickness was returned to 100 mm, the casting speed was restored to 5.0 m/min, which is the normal casting speed. During operation, the solidifying front was always located at a place upstream from the roll reduction finishing area.

Using the second strand casting machine as a comparative example, restoration of the cast slab was carried out by releasing the roll reduction force immediately after the changing point of the slab passed the roll reduction zone while maintaining the normal casting speed. Fig. 3 is a graph showing a variation in the casting speed and slab thickness with respect to elapse of the casting period. As is apparent from the graph, increase in the slab thickness, i.e., opening of the roll gaps at the point of the roll reduction finishing area proceeded continuously.

Figs. 4 and 5 illustrate shapes of unstable areas of cast slabs which were obtained by the thickness restoring operations of an example of the present invention and a comparative example, respectively. In the drawings, the direction of the arrow indicates the direction of drawing of a cast slab, i.e., the casting direction.

As shown in Fig. 4, it is possible in the first strand casting machine to which the process of the present invention was applied to change the slab thickness from 50 mm to 100 mm smoothly in the transitional area.

On the other hand, as shown in Fig. 5, according to the comparative example in which the second strand casting machine was employed, the cast slab in the transitional area swelled like a drum due to the occurrence of bulging.

The resulting cast slabs were cut and examined on their cross sections. Cast slabs from the first strand to which the process of the present invention was applied were free from internal defects even in a transition area where the slab thickness was increased gradually. Further rolling following the continuous casting was carried out successfully, resulting in a coil having good quality. On the other hand, the cast slabs obtained from the second strand to which an immediate release of the roll reduction force was applied, as shown in Fig. 6, suffered from internal cracking and breaking into two pieces in the barrel-like swollen portion of the slab. Regarding central segregation, heavy normal and inverse segregation was found in scattered places, resulting in troubles such as formation of internal defects at the time of subsequent rolling.

Thus, according to the process of the present invention, in which the roll reduction force is released during squeeze reduction, it is possible to change the slab thickness successfully without any degradation in internal quality of the slab, resulting in a marked improvement in yield.

(Example 2)

This example was carried out to evaluate the influence of the type of steel. Example 1 was repeated, and low carbon, Al-killed steel having the steel composition shown in Table 2 was cast at a normal casting speed of 5.0 m/min. In this example, too, the casting speed at which a cast slab was completely solidified before it passed the roll reduction finishing area was 1.3 m/min for a slab thickness of 100 mm.

Table 2 (%by weight)

C	Si	Mn	P	S	Al	Fe
0.05	0.045	0.85	0.015	0.008	0.045	bal.

The results of this example were as follows.

According to a process of the present invention, changing of the cast slab thickness was achieved smoothly, and the resulting slab was free from internal cracking and central segregation in the unstable area and had a good quality.

On the other hand, in the comparative example, when the unstable area was expanded from 50 mm to 100 mm upon release of the roll reduction force, as shown in Fig. 5, swelling like a drum occurred and formation of central segregation and degradation in porosity were found, although internal cracking did not occur.

Fig. 7 shows a comparison of the internal quality of the resulting cast slabs of the example of the present invention and the comparative example. The code number on the Y-axis is a numerical indication of inner quality of the resulting slabs based on the following definition.

Code Number	Porosity area/10 cm^2 of horizontal area
0	0 %
1	0 - 10%
2	10 - 30%
3	30 - 50%
4	50 - 70%
5	70% or more

Thus, compared with the case of medium carbon steel of Example 1, it is noted that although there was a little less degradation in inner quality in this comparative example, the yield was still as low as in the comparative example of Example 1.

(Example 3)

This example was carried out to evaluate the influence of the casting speed. Example 1 was repeated, and medium carbon, Al-killed steel having the steel composition shown in Table 1 was cast at a normal casting speed of 5.0 m/min. However, in this example, although a target slab thickness to be restored from the slab thickness of 50 mm was set to be 100 mm, the casting speed was varied to 1.3, 2.0, and 3.0 m/min by adjusting the deceleration rate at the beginning of restoration of the thickness. In this example, the casting speed at which a cast slab was completely solidified before it passed the roll reduction finishing area was 1.3 m/min.

In the case of the present invention, since the casting speed was changed to 1.3 m/min, the thickness of the cast slab was successively changed from 100 mm to 50 mm and then to 100 mm. The resulting cast slabs were free from internal cracking, and a degradation in the central segregation was not found.

On the other hand, in the case of the comparative example, since the casting speed was lowered to a rather high level of 2.0 m/min or 3.0 m/min, the solidified shell thickness was 40 mm and 33 mm, respectively, in the roll reduction finishing area, and an unsolidified portion remained when the slab passed the roll reduction finishing area. As a result, as shown in Fig. 5, the unstable portion of the slab swelled like a barrel upon release of the roll reduction force. In the slab, there were occurrence of internal cracking, degradation in central segregation, and an increase in porosity, resulting in a reduction in the yield when the casting speed was 2.0 or 3.0 m/min at the time of release of the roll reduction force.

According to the present invention, during operation of continuous casting, it is possible to change the thickness of cast slabs, without a degradation in surface conditions and inner quality, and a variety of sizes of slabs can be produced efficiently with a high yield.

Claims

1. A continuous casting and squeeze reduction process for producing thin slabs, in which cast slabs having an unsolidified portion are reduced in thickness in a roll reduction zone, characterized in that while a solidifying front is kept at a point upstream of a roll reduction finishing area, a roll reduction force is released during squeeze reduction to change the thickness of the slab to a target thickness.

2. A continuous casting and squeeze reduction process for producing thin slabs in which cast slabs having an unsolidified portion are reduced in thickness in a roll reduction zone, characterized in that the casting speed is changed to a casting speed which is lower or higher than the casting speed at which the cast slab having a target thickness after a change in thickness can be completely solidified within a squeeze reduction zone, the roll reduction force is released until a target thickness of the slab is achieved, and then the casting speed is changed to a given casting speed.

3. A continuous casting process for thin slabs as set forth in Claim 2 wherein a change in the casting speed is started at the same time when a changing point of the slab passes a roll reduction finishing area.

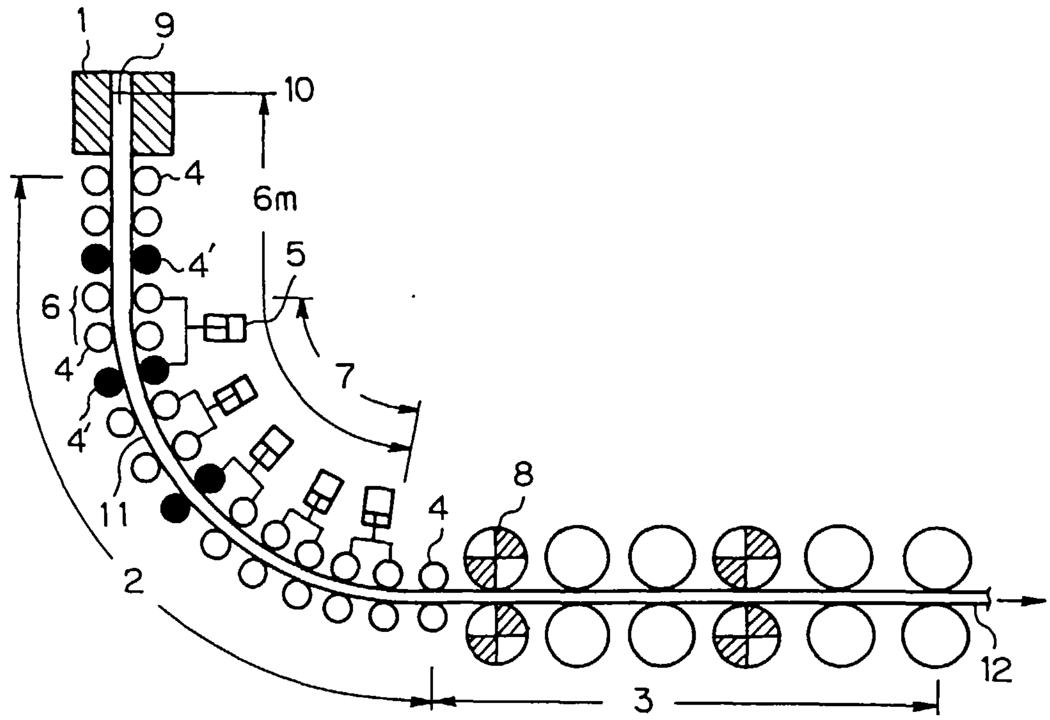
4. A continuous casting process for thin slabs as set forth in Claim 2 wherein a change in the casting speed is started before the time when a changing point of the slab passes a roll reduction finishing area.

5. A continuous casting and squeeze reduction process for producing thin slabs in which cast slabs having an unsolidified portion are reduced in thickness in a roll reduction zone, characterized in that the casting speed is changed to a casting speed which is lower than the casting speed at which the cast slab having a target thickness after a change in thickness can be completely solidified within a squeeze reduction zone, the roll reduction force is released until a target thickness of the slab is achieved, and then the casting speed is increased to a given casting speed.

6. A continuous casting process for thin slabs as set forth in Claim 5 wherein a decrease in the casting speed is started at the same time when a changing point of the slab passes the roll reduction finishing area.

7. A continuous casting process for thin slabs as set forth in Claim 5 wherein a decrease in the casting speed is started before the time when a changing point of the slab passes the roll reduction finishing area.

Fig. 1


1
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10
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4'
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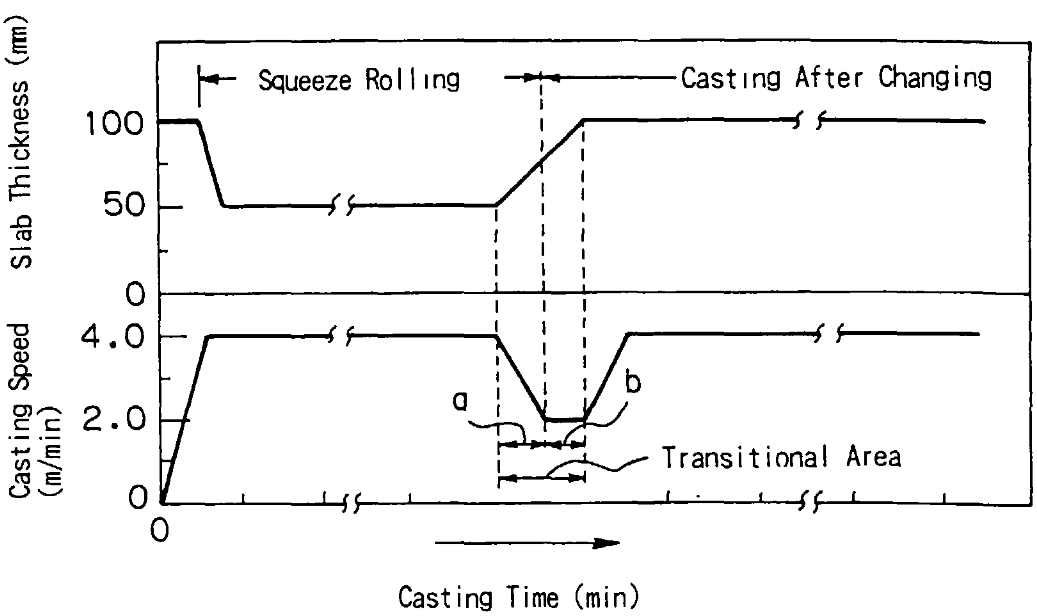
Fig. 2


Slab Thickness (mm)
Squeeze Rolling
Casting After Changing
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50
0
4.0
2.0
0
Casting Speed (m/min)
a
b
Transitional Area
0
Casting Time (min)

Fig. 3

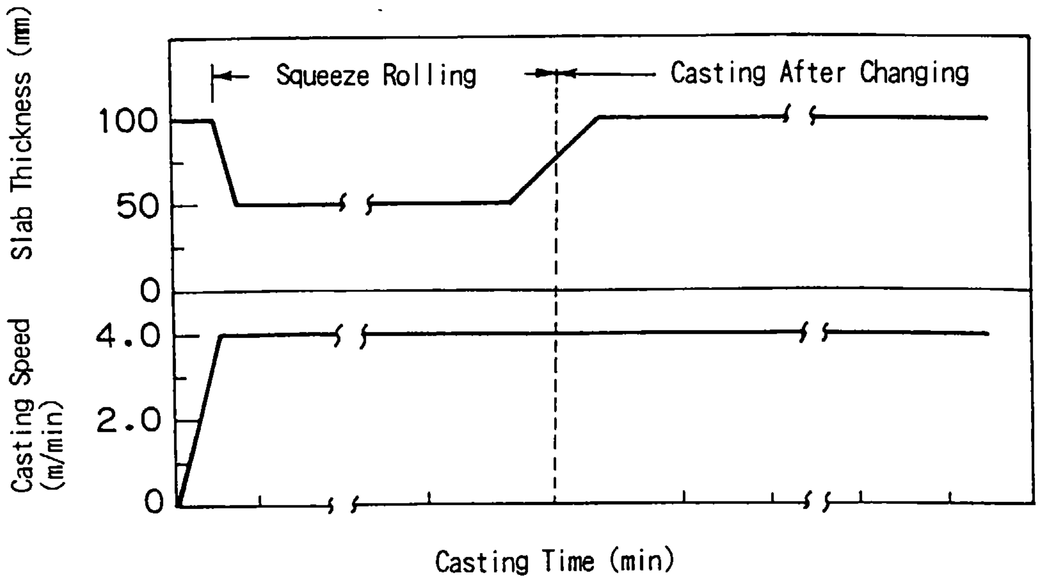


Fig. 4

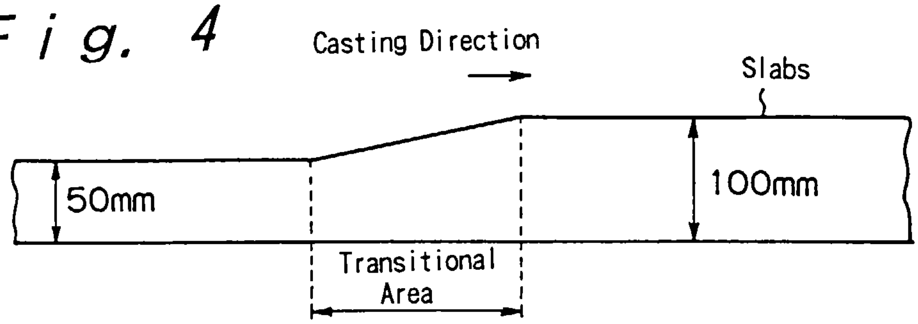


Fig. 5

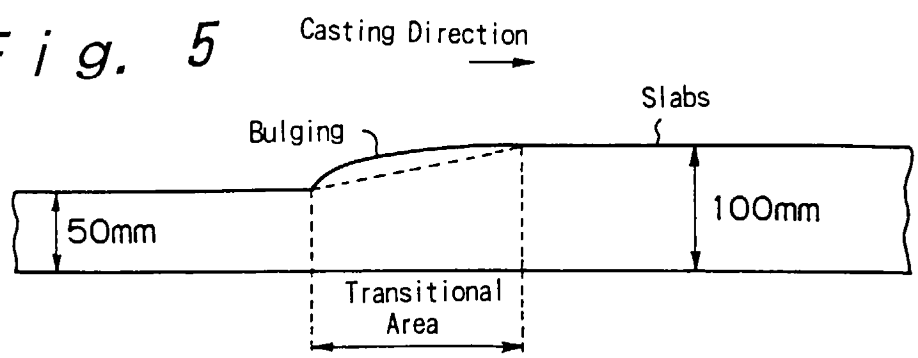


Fig. 6

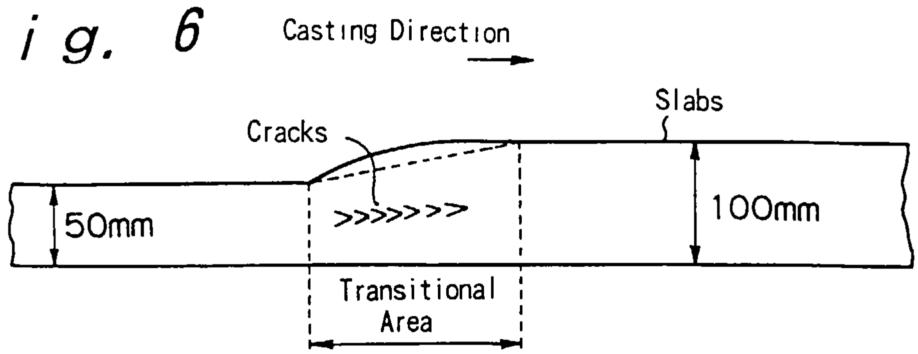
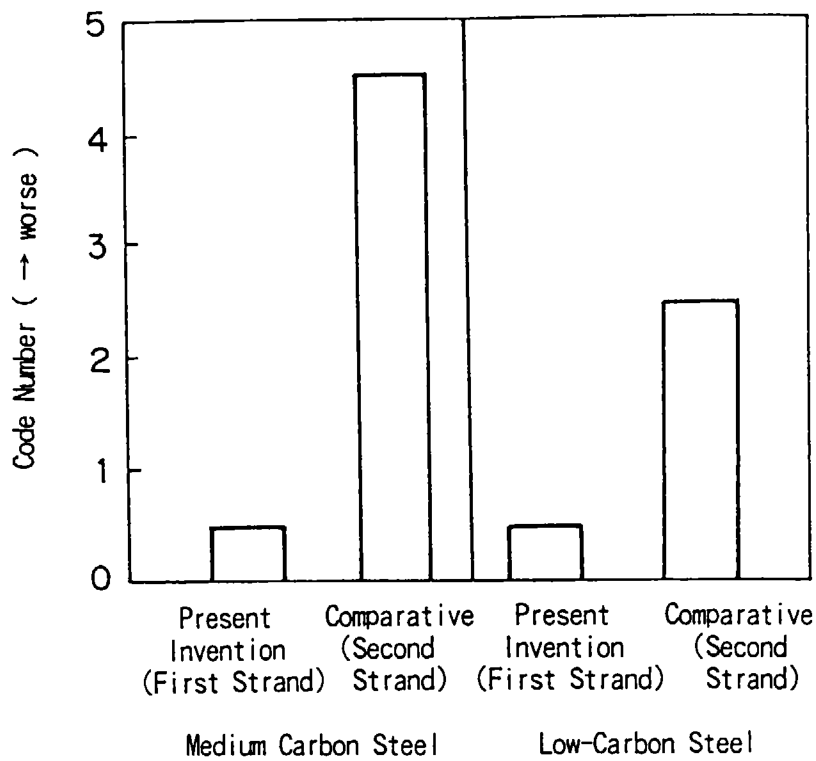


Fig. 7


Code Number (→ worse)
0
1
2
3
4
5
Present Invention (First Strand)
Comparative (Second Strand)
Present Invention (First Strand)
Comparative (Second Strand)
Medium Carbon Steel
Low-Carbon Steel

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/01701

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 B22D11/20

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)

Int. Cl^6 B22D11/128, B22D11/16, B22D11/20

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

Jitsuyo Shinan Koho	1926 - 1996
Kokai Jitsuyo Shinan Koho	1971 - 1995
Toroku Jitsuyo Shinan Koho	1994 - 1996

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 1-271047, A (Sumitomo Metal Industries, Ltd.), October 30, 1989 (30. 10. 89)(Family: none)	1 - 7
A	JP, 58-13454, A (Nippon Steel Corp.), January 25, 1983 (25. 01. 83)(Family: none)	1 - 7
A	JP, 53-102224, A (Ishikawajima-Harima Heavy Industries Co., Ltd.), September 6, 1978 (06. 09. 78)(Family: none)	1 - 7
A	JP, 54-22777, B2 (NKK Corp.), August 9, 1979 (09. 08. 79) & DE, 2444443, A & FR, 2243750, A & CA, 1029528, A	1 - 7

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

- * Special categories of cited documents:
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- "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
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- "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
September 13, 1996 (13. 09. 96)	September 24, 1996 (24. 09. 96)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)