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(54) **METHOD OF CONTINUOUSLY CASTING DOUBLE-LAYERED METALLIC MATERIAL.**

(57) A method of controlling the rate of feeding a molten metal in a continuous production of a double-layered metallic material in which the composition of an outer layer is different from that of an inner layer from the molten metal. A DC magnetic flux crossing the direction of the thickness of a cast piece is applied to the interior of a continuous casting mold over the whole width thereof, and two kinds of molten metals of different compositions are supplied to the upper and lower sides of a magnetostatic field zone (3) formed in the casting direction by DC magnetic flux. The quantity Q2 per unit time of the metal supplied to the lower side of the magnetostatic field zone (3) is controlled so that the level of the molten metal becomes constant as the quantity Q1 per unit time of the metal supplied to the upper side of the magnetostatic field zone (3) is maintained at a set level. The continuous casting method according to the present invention enables the separation of the components of the outer and inner layers from each other to be carried out excellently, and the thickness of the outer layer to be set uniform in the continuous production of a double-layered metallic material, in which the chemical composition of the outer layer is different from that of the inner layer, from molten metal.

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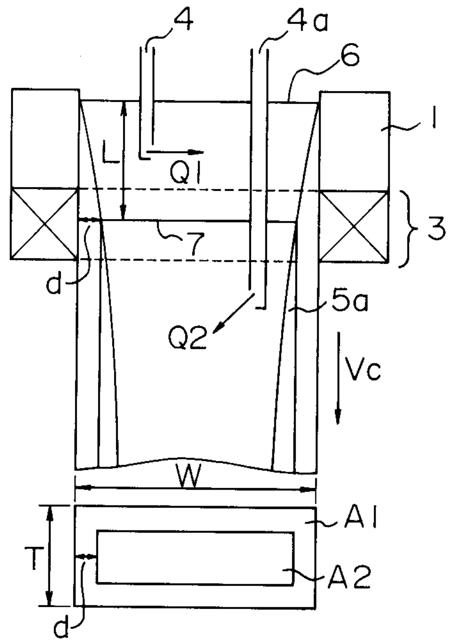
F I G. 1



TECHNICAL FIELD

The present invention relates to a molten metal supply control method to be used when continuously producing from a molten metal a double-layered metal material composed of surface and inner layers whose compositions, i.e., chemical compositions, are different from each other.

BACKGROUND ART

There have been disclosed in Japanese Patent Laid-Open No. 63-108947, etc., continuous casting methods for producing double-layered metal materials, according to which, as shown in Fig. 2, a DC magnetic flux extending across the thickness of a cast piece is applied inside a continuous casting mold 1 over the entire width thereof, and two kinds of molten metals having different compositions are separately supplied to upper and lower mold sections bordered by a magnetostatic field zone 3 formed to extend along a vertical direction (i.e., in a casting direction) of the mold by the DC magnetic flux.

Further, there have been disclosed in Japanese Patent Laid-Open No. 3-243262, etc., methods of controlling molten metal supply amounts for use in the above process, according to which the sum of the supply amounts of the two kinds of metals is adjusted while maintaining the ratio between the supply amounts of these two kinds of metals constant, thereby controlling the molten metal surface level in the mold, or, while maintaining the supply amount of the metal on the lower side (the metal on the downstream side) at a preset value, the supply amount of the metal on the upper side is adjusted, thereby controlling the molten metal surface level in the mold.

While there have thus been indicated in the prior-art techniques the basic concepts of the continuous casting method for producing double-layered metal materials by utilizing a magnetostatic field zone formed by a DC magnetic flux and methods of controlling molten metal supply amounts, these prior-art techniques have a problem in that they do not always provide a sufficient degree of controllability with respect to operational fluctuations caused by bulging or shrinkage of an unsolidified cast piece below the lower section of the mold, resulting in, for example, an insufficient component separation between the surface and inner layers of the double-layered metal material obtained, a fluctuation in the thickness of the surface layer, or unevenness in the quality characteristics of the resultant products.

It is the object of the present invention to provide a continuous casting method for producing double-layered metal materials which makes it possible to eliminate the above problems in the prior-art techniques.

DISCLOSURE OF THE INVENTION

In accordance with the continuous casting method of the present invention, a DC magnetic flux extending across the thickness of a cast metal is applied inside a continuous casting mold over the entire width thereof at a position spaced apart downstream by a predetermined distance in the casting direction from the molten steel meniscus, and two kinds of molten metals having different compositions are supplied to upper and lower mold sections respectively (respectively on the upstream and downstream sides thereof) bordered by a magnetostatic field zone formed to extend across the casting direction by the DC magnetic flux, wherein the metal supply per unit time for the mold section underneath the magnetostatic field zone is controlled in such a way so as to make the molten metal level constant while maintaining the metal supply per unit time for the upper mold section above the magnetostatic field zone at a preset value. Here, the above-mentioned preset value depends upon the type of equipment, the composition, molten metal temperature of the surface layer and casting speed and, in particular, the preset value depends on the casting speed very much. Thus, when the casting rate is constant, the preset value is also constant.

The operation of the present invention will now be described in detail

Fig. 1 schematically shows a cross-sectional view of two kinds of metals respectively on either side of their boundary inside a mold. Assuming that the cross-sectional area of the metal of the surface layer (which is on the upper side) is A1, and that the cross-sectional area of the metal of the inner layer (which is on the lower side) is A2, these cross-sectional areas can be expressed by the following equations, (1) and (2):

$$A1 = TW - (T - 2d) \bullet (W - 2d) \qquad (1)$$

$$A2 = (T - 2d) \bullet (W - 2d) \qquad (2)$$

where

T: in-mold thickness (cast piece thickness)
W: in-mold width (cast piece width)

Symbol d indicates the thickness of the surface layer metal (the solidification shell thickness), which can be expressed by the following equation:

$$d = K(L/Vc)^n \quad (3)$$

where
L : distance from the meniscus to the boundary (m)
Vc: casting speed (m/min)

Symbols K and n indicate coefficients peculiar to the process, which usually assume approximately the following values: $K = 25\ mm \cdot min^{-1/2}$, and $n = 0.5$, and are little influenced by the operating conditions. Accordingly, the solidification thickness d of the surface layer metal at the boundary between the two kinds of metals is a value which is determined substantially definitely when the casting speed is determined.

Assuming that the respective densities of the surface and inner layer metals in ideal casting conditions are r1 and r2, their supply amounts per unit time can be expressed by the following equations, (4) through (6):

$$Q1 = r1 \cdot A1 \cdot Vc \quad (4)$$

$$Q2 = r2 \cdot A2 \cdot Vc \quad (5)$$

$$Q = Q1 + Q2 \quad (6)$$

where
Q1: supply amount per unit time of the molten metal for the upper (surface) layer
Q2: supply amount per unit time of the molten metal for the lower (inner) layer
Q3: total supply amount consisting of the sum of the supply amounts for the surface and inner layers

However, in actual continuous metal casting, bulging of the unsolidified portion between support rolls, or fluctuation in actual volume due to thermal shrinkage or solidification shrinkage, occurs, so that the total supply amount Q', which is the sum of the supply amounts for the surface and inner layers, also fluctuates. This fluctuation, however, mostly occurs in the unsolidified portion below the lower section of the mold, so that in the continuous casting of a double-layered metal material, the supply amount per unit time Q2' of the molten metal for the lower layer fluctuates. Thus, the supply amount per unit time Q1' of the upper molten metal is substantially free from the influence of the fluctuation in the total supply mount.

Thus, assuming that Δ indicates the variation, the actual supply amounts Q1', Q2' and Q' can be expressed by the following equations, (7) through (9):

$$Q1' = Q1 \quad (7)$$

$$Q2' = Q2 + \Delta \quad (8)$$

$$Q' = Q1' + Q2' \quad (9)$$

According to the prior-art technique as disclosed in Japanese Patent Laid-Open No. 3-243262, the supply amount per unit time Q1' of at least the upper molten metal is controlled with respect to the operational fluctuations as mentioned above, so that when the meniscus molten metal level is maintained at a constant level, the distance L from the meniscus to the boundary fluctuates, and the magnetostatic field zone is departed from, resulting in an insufficient separation between the components of the surface and inner layers, or unevenness in the thickness d of the surface layer, as is apparent from equation (3).

In accordance with the present invention, in contrast, the supply amount per unit time Q1' of the upper molten metal is a value determined by a preset value, that is, by the casting rate, as indicated by the basic concept expressed by equations (7) through (9), so that the boundary is controlled to have a constant position even under operational fluctuations, such as bulging of the unsolidified portion between support rolls or variation in actual volume due to thermal shrinkage or solidification shrinkage. Therefore, it is possible to solve such problem that the boundary is moved out of the magnetostatic field zone to thereby cause an insufficient component separation between the surface and inner layers or the there occurs unevenness in the surface layer thickness d, thereby making it possible to produce a double-layered metal material whose quality is satisfactory and stable.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram schematically showing a cross-sectional view of two kinds of metals respectively on either side of their boundary inside a mold; and

Fig. 2 is a sectional view schematically showing how the metals are poured into the mold.

BEST MODE FOR CARRYING OUT THE INVENTION

For the present invention to be more fully understood, a description thereof will be given below with reference to the accompanying drawings.

Two kinds of molten steels as shown in Table 1: (1) 18-8 stainless steel and (2) ordinary low carbon steel, were held in separate tundishes. As shown in Fig. 2, molten steel (1) was poured into the mold section above a magnetostatic field zone 3, and molten steel (2) was poured into the mold section below the same, by using separate immersion nozzles 4 and 4a, respectively.

Table 1 (unit: wt%)

	C	Si	Mn	P	S	C	Ni
(1)	0.04	0.49	1.01	0.01	0.01	18.1	8.50
(2)	0.01	0.03	0.24	0.01	0.01	0	0

The continuous casting mold 1 used had a size of 250 mm (thickness) x 1200 mm (width), and the casting speed was 1.0 m/min. The position of the magnetostatic field zone 3 was from 450 to 700 mm below (downstream) a meniscus 6 inside the mold 1, and the intensity of the DC magnetic flux was 0.5 tesla.

Table 2 shows the results of an examination of the cast component separation between the surface and inner layers and the surface layer thickness of cast pieces obtained through supply amount control of two kinds of metals by the method in accordance with the present invention and prior-art techniques.

Table 2

	Surface layer supply	Inner layer supply	Separation index[1)]	Variation in surface layer thickness[2)]
Prior art 1	Adjusted	Adjusted	0.92±0.08	±4 mm
Prior art 2	Adjusted	Set value	0.90±0.10	±5 mm
Present invention	Set value	Adjusted	0.98±0.02	±1 mm

(Notes)

1) Separation index = $(C1 - C2)/(C1^0 - C2^0)$

where

C1: solute density of the surface layer of the cast piece

C2: solute density of the inner layer of the cast piece

$C1^0$: solute density of the molten steel supplied to the surface layer

$C2^0$: solute density of the molten steel supplied to the inner layer

2) Variation in surface layer thickness: deviation from the average thickness

It can be appreciated from the above results that in the example according to the present invention, an improvement had been achieved in terms of the absolute value and variation of the separation index and the variation of the surface layer thickness as compared with the prior-art examples. Further, in the prior-art examples, molten metal supply amount for the surface layer was increased in relation to operational fluctuations, with the result that the boundary was shifted downwards to cause the surface layer metal to be mixed with the inner layer metal to a large degree, and the that tendency of the thickness of the surface layer to increase was to be observed.

INDUSTRIAL APPLICABILITY

In accordance with the present invention, an improvement can be achieved in terms of the component separation between the surface and inner layers when producing a double-layered metal material by continuous casting, and it is possible to produce a double-layered metal material whose surface layer has a uniform thickness.

Claims

1. A continuous casting method for double-layered metal materials of the type in which a DC magnetic flux extending across the thickness of a cast piece is applied inside a continuous casting mold over the entire width thereof at a position spaced apart downstream in a casting direction by a predetermined distance from a molten steel meniscus in the continuous casting mold, and in which two kinds of molten metals having different compositions are supplied respectively to upper and lower mold sections bordered by a magnetostatic field zone formed to extend across the casting direction by the DC magnetic flux, a metal supply amount per unit time for the lower mold section below the magnetostatic field zone being controlled to keep the molten metal surface at a constant level while maintaining the metal supply amount per unit time for the mold section above the magnetostatic field zone at a preset value.

2. A method according to Claim 1, wherein said double-layered metal material includes an surface layer portion and an inner layer portion having a composition different from that of said surface layer portion.

3. A method according to Claim 2, wherein the molten metal forming the surface layer portion is supplied to the mold section on the upstream side of the magnetostatic field zone directly or through an immersion nozzle whose outlet end is located on the upstream side of the magnetostatic field zone, and the molten metal forming the inner layer portion being supplied to the mold section on the downstream side of the magnetostatic field zone through an immersion nozzle whose outlet end is located on the downstream side of the magnetostatic field zone.

4. A method according to one of Claims 1 through 3, wherein the magnetostatic field zone is located inside the continuous casting mold.

5. A method according to Claim 4, wherein the magnetostatic field zone is located on the downstream side in the casting direction of the mold inside the continuous casting mold.

6. A method according to one of Claims 2 through 5, wherein the surface layer portion consists of stainless steel, and the inner layer portion consists of a low carbon steel.

FIG. 1

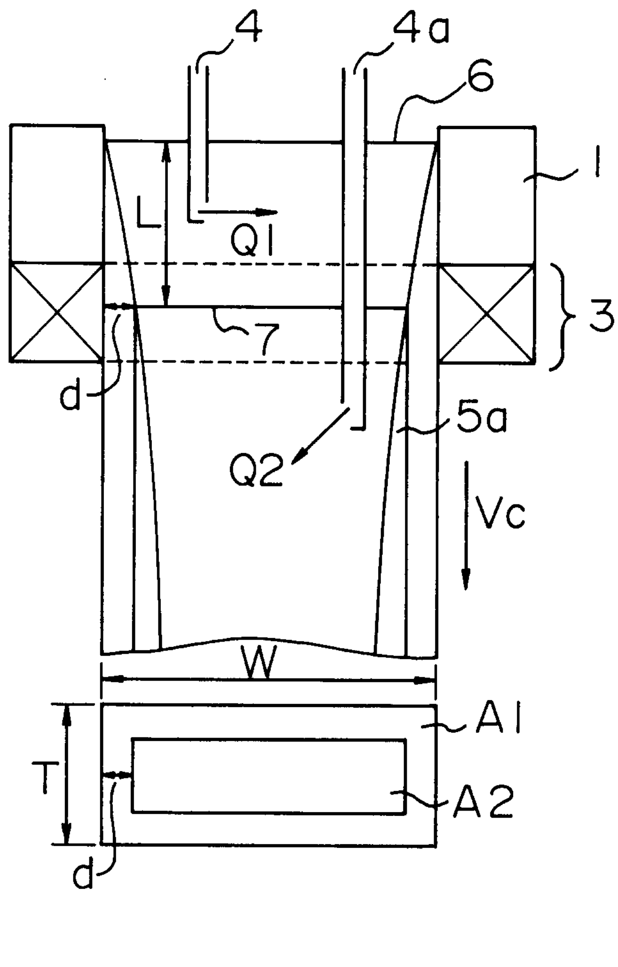
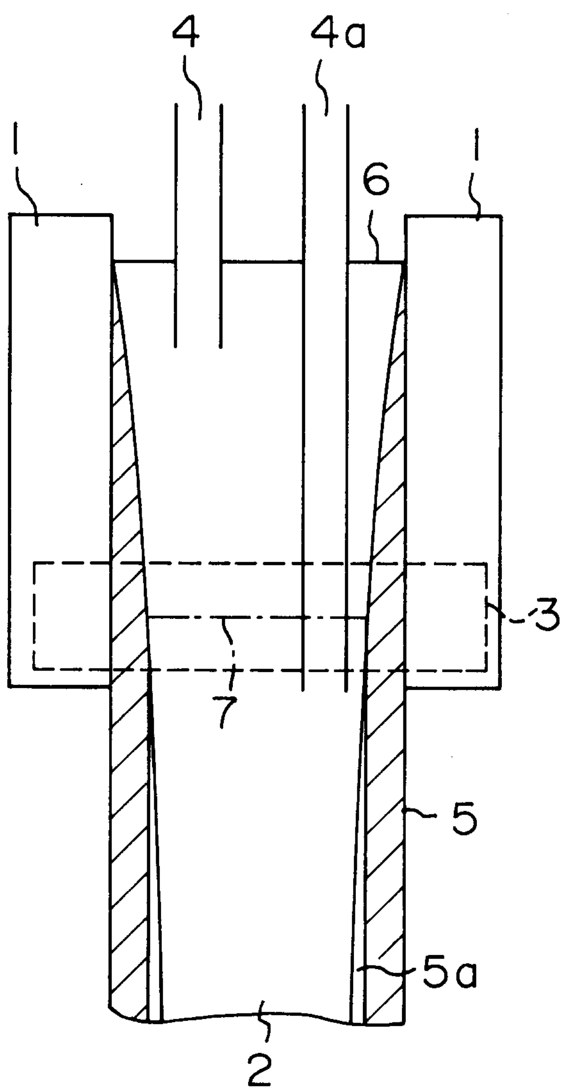


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP93/00412

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^5 B22D11/00, 11/18

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^5 B22D11/00-11/22

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

Jitsuyo Shinan Koho	1926 - 1993
Kokai Jitsuyo Shinan Koho	1971 - 1993

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, B2, 3-20295 (Nippon Steel Corp.), March 19, 1991 (19. 03. 91), & EP, B1, 265235 & US, A, 4828015 & DE, CO, 3767278	1-6
A	JP, A, 3-243264 (Nippon Steel Corp.), October 30, 1991 (30. 10. 91), (Family: none)	1-6
A	JP, A, 3-66447 (Nippon Steel Corp.), March 22, 1991 (22. 03. 91), (Family: none)	1-6
A	JP, A, 64-66052 (Nippon Steel Corp.), March 13, 1989 (13. 03. 89), (Family: none)	1-6

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
June 10, 1993 (10. 06. 93)	June 29, 1993 (29. 06. 93)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
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