(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 222 321**
B1

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of the patent specification: **08.08.90**

(51) Int. Cl.[5]: **B22D 11/04**, B22D 11/07, B22D 11/10

(21) Application number: **86115363.3**

(22) Date of filing: **05.11.86**

(54) **Method for preventing mold exlosions during continuous casting of free machining steels.**

(30) Priority: **12.11.85 US 796992**

(43) Date of publication of application:
20.05.87 Bulletin 87/21

(45) Publication of the grant of the patent:
08.08.90 Bulletin 90/32

(84) Designated Contracting States:
BE CH DE FR GB IT LI SE

(56) References cited:
CH-A- 455 165
GB-A- 2 027 375
US-A- 4 120 344
US-A- 4 165 780

(73) Proprietor: **INLAND STEEL COMPANY, 30 West Monroe Street, Chicago, IL 60603(US)**

(72) Inventor: **Pielet, Howard M., 7942 Frederick Ave., Munster, IN 46321(US)**
Inventor: **Bhattacharya, Debanshu, 5159 Keith Drive, Richton Park, Il 60471(US)**

(74) Representative: **Leach, John Nigel et al, FORRESTER & BOEHMERT Widenmayerstrasse 4/I, D-8000 München 22(DE)**

EP 0 222 321 B1

Description

The present invention relates generally to the continuous casting of free-machining steels and more particularly to a method for preventing mold explosions during the continuous casting of molten steel containing at least one of lead and bismuth.

In a vertical continuous casting operation, molten steel is flowed from a ladle into a intermediate container called a tundish having a plurality of spigots in its bottom through which molten steel is flowed into a casting mold having an open upstream end and sidewalls extending from the upstream end to a downstream end initially closed by a so-called "dummy bar". The sidewalls of the mold are cooled, e.g. with a water jacket, and the molten steel initially contacting the dummy bar and the side-walls solidifies to form a solid shell enclosing unsolidified molten steel. After this initial solidification forming a solid shell, the dummy bar is withdrawn from the mold's downstream end, and the solidified shell containing unsolidified molten steel advances through the mold in a downstream direction, e.g. under the urging of gravity. The portion of the mold vacated by the shell's downstream movement is replenished with additional molten steel.

To facilitate the movement of the partially solidified steel through the mold and to prevent the solidified steel shell from sticking to the inside surface of the mold, a lubricant is employed. The lubricant is typically an organic compound such as a petroleum-base oil, and the lubricant is typically applied to the interior surface of the mold before the casting operation begins. Lubricants are also injected between the molten steel and the interior surface of the mold walls during the casting operation. Typical examples of lubricants employed during the continuous casting of molten steel are set forth in Borg, et al U.S. Patent No. 4 120 344.

There are problems which occur during the continuous casting of steel containing machinability increasing ingredients such as bismuth, lead and tellurium, which do not ordinarily occur during the continuous casting of molten steel not containing these ingredients. In the continuous casting of molten steel containing any of these ingredients, expositions occur within the mold when the mold is lubricated with conventional lubricants.

Some attempts have been made in the past to solve these problems. Thus Borg et al, U.S. Patent No. 4 120 344 teaches the prevention of explosions in tellurium-containing steel by employing, as the mold lubricant, a white mineral oil. Although this expedient prevents mold explosions during the continuous casting of tellurium-containing molten steel, it does not prevent mold explosions during the continuous casting of molten steel containing bismuth.

GB-A 2 027 375 discloses the operation of a continuous casting mold for the continuous casting of molten steel, wherein said molten steel is introduced into a continuous casting mold having an interior surface, said molten steel is at least partially solidified in said mold to form a solid shell, and said interior surface is lubricated with a non-metallic, non-organic mold lubricant to prevent the sticking of said shell to said interior surface during the cast. However, the continuous casting mold is horizontally disposed and the lubricant is a relatively permanent electroplated coating of nickel or chromium in which is disposed a solid non-organic lubricant material and the metal being cast does not contain bismuth and lead in machinability increasing amounts.

Engeler, U.S. Patent No. 4 165 780 discloses a method for preventing mold explosions in the continuous casting of molten steel containing lead according to the preamble to Claim 1. Engeler teaches that mold explosions can be avoided by eliminating the use of oil as a mold lubricant and by employing, as the mold lubricant, a mixture of a liquid inert gas (e.g. nitrogen) and a flux powder (e.g. carbon particles) applied atop the molten steel in the mold while at the same time oscillating the mold back and forth along the path of movement of the steel through the mold. The mixture of inert gas and flux powder forms a layer atop the molten steel, and the thickness of the layer is controlled so that it is less than the length of the stroke of the oscillating mold.

A method in accordance with the present invention eliminates mold explosions during the vertical continuous casting of molten steel containing bismuth or lead, without employing the complicated procedure described in Engeler.

In accordance with the present invention we provide a method for the vertical continuous casting of free machining steels containing at least one of the elements bismuth and lead, wherein (a) said molten steel is introduced into a continuous casting mold having an interior surface, (b) said molten steel is at least partially solidified in said mold to form a solid shell, (c) said interior surface is lubricated with a non-metallic, non-organic mold lubricant to prevent the sticking of said shell to said interior surface during the cast, (d) said lubricant is applied in a transitory manner wherein the lubricant wears off during a casting operation, (e) said lubricant is thermally and chemically relatively passive, in the presence of molten steel containing lead and/or bismuth, under the conditions existing within said mold, to avoid explosions, (f) said lubricant is incapable of producing a breakdown compound, under said conditions, which is explosive under said conditions, and (g) there is excluded from said mold any organic compound which produces explosions under said conditions; and applying directly to the interior surface of said mold, before the start of each casting operation, a lubricant devoid of liquified gas.

A preferred lubricant in accordance with the present invention is molybdenum disulfide. Other lubricants which may be used in accordance with the present invention are lithium sulfide and graphite.

Any organic compounds, including oils, and other conventional lubricants heretofore used during the continuous casting of molten steel, which produce explosions when the molten steel contains bismuth or lead, are excluded from the mold. The non-organic compound employed as a lubricant in accordance with the present invention is devoid of liquified inert gases, such as liquid nitrogen.

The method of the present invention may further comprise providing a lubricant-containing layer atop the molten steel in said mold no earlier than when the mold has been at least partially filled with said molten steel; maintaining said layer atop the molten steel substantially throughout the casting operation; and oscillating said mold back and forth along the path of movement of said steel through said mold, said oscillation having a predetermined stroke length; the thickness of said lubricant-containing layer being independent of the length of the stroke of the oscillating mold.

In addition to at least one of lead and bismuth, the molten steel may also contain tellurium and the method of the present invention is equally effective in preventing mold explosions when tellurium is additionally present in the molten steel.

The lubricant-containing layer may comprise a flux powder which is chemically and thermally relatively passive in the presence of molten steel containing lead and/or bismuth, under the conditions of continuous casting existing within the mold, to avoid explosions, and being incapable of producing a breakdown compound, under said conditions, which is explosive under said conditions.

Other features are inherent in the method claimed and disclosed or will become apparent to those skilled in the art from the following detailed description.

The present invention is employed in connection with molten steel containing at least one of the machinability increasing ingredients lead and bismuth, alone or in combination, in machinability increasing amounts. The steel may also contain tellurium as an additional machinability increasing ingredient. Typical examples of machinability increasing amounts for each of these ingredients are:
0.05–0.50 wt.% lead; 0.04–40 wt.% bismuth; and 0.02–0.06 wt.% tellurium. The present invention is applicable to any steel composition heretofore containing these elements as described in the preceding part of this paragraph.

Molten steel having a composition in accordance with the preceding paragraph is introduced into a vertically disposed continuous casting mold having sidewalls with an interior surface coated with a lubricant in accordance with the present invention.

The lubricant is preferably molybdenum disulfide. Other lubricants which may be employed comprise lithium sulfide and powdered graphite. This lubricant does not contain liquified inert gases, such as liquid nitrogen.

The lubricant is applied to the interior surface of the mold walls before the molten steel is introduced into the mold. When the casting mold is coated with such a lubricant at the start of the cast, the solid steel shell with incompletely solidified molten steel therein advances through the mold without sticking to the side walls of the mold, and there are no mold explosions.

Excluded from the interior of the mold is any organic compound which produces explosions under the conditions existing within the mold during continuous casting,. Thus excluded from the mold are petroleum based oils conventionally used as a mold lubricant in the continuous casting of molten steel, and this includes white mineral oil among the excluded organic compounds when the molten steel contains bismuth.

After the casting mold has been at least partially filled with molten steel, a flux powder composed of non-organic material is added atop the molten steel and maintained there during substantially the rest of the casting operation. The flux powder may be of any conventional composition heretofore used for that purpose provided that the flux powder is not violently reactive chemically or thermally, under the conditions of continuous casting existing within the mold, to produce explosions, and does not break down under such conditions to produce a compound which is explosive under such conditions. Such flux powder can also provide a lubricant between the molten steel and the interior surface of the mold walls at a time during the casting operation when the lubricant applied before the start of the casting operation has worn off. Three examples of such flux powders, identified as A-C respectively, are substantially as set forth below.

INGREDIENT	PARTS BY WEIGHT		
	A	B	C
SiO_2	11	28	28
Al_2O_3	1	13	1.5
MgO	0.5	1	0.1
CaO	11	23	3
CaF_2	40	12	16
Na_2O	18	5	28
B_2O_3	16	0.4	1
C	0.2	6	0.3
FeO	0.3	4	0.1
P_2O_5	–	–	12

During the casting operation, the mold may be oscillated back and forth along the path of movement of the steel through the mold (i.e., up and down oscillation). The oscillation has a predetermined stroke length, but there is no requirement that one relate the thickness of any lubricant-containing layer atop the molten steel in the mold to the length of the stroke of the oscillating mold.

It may also be desirable to position in the bottom of the mold, just above the dummy bar, an aluminum deoxidant typically in the form of an aluminum wire strung back and forth across the interior of the mold, near the bottom thereof, before the start of the casting operation. A typical continuous casting mold with which the present invention is employed has cross sectional dimensions of 360 mm by 520 mm and a depth of 500 mm to the dummy bar, at the start of the casting operation. In such a mold, about 150 grams of aluminum wire is employed.

The lubricant employed in the present invention is not violently reactive thermally or chemically under the conditions of continuous casting existing within the mold, and thus it will not produce explosions, and it does not break down under those conditions to produce a compound which is explosive under those conditions. This is in contrast to lubricating oils conventionally utilized as a mold lubricant in the continuous casting of molten steel. Such lubricants will cause mold explosions when the steel contains lead, bismuth or tellurium, and thus must be excluded from the mold during the continuous casting of molten steel containing those ingredients. White mineral oil, heretofore employed as a lubricant for molten steel containing tellurium may not be employed as a lubricant when the molten steel contains bismuth because the white mineral oil will cause mold explosions if employed in the continuous casting of molten steel containing that ingredient.

Claims

1. A method for the vertical continuous casting of free machining steels containing at least one of the elements bismuth and lead, wherein (a) said molten steel is introduced into a continuous casting mold having an interior surface, (b) said molten steel is at least partially solidified in said mold to form a solid shell, (c) said interior surface is lubricated with a non-metallic, non-organic mold lubricant to prevent the sticking of said shell to said interior surface during the cast, (d) said lubricant is applied in a transitory manner wherein the lubricant wears off during a casting operation, (e) said lubricant is thermally and chemically relatively passive, in the presence of molten steel containing lead and/or bismuth, under the conditions existing within said mold, to avoid explosions, (f) said lubricant is incapable of producing a breakdown compound, under said conditions, which is explosive under said conditions, and (g) there is excluded from said mold any organic compound which produces explosions under said conditions; said method being characterized by the step comprising: applying directly to the interior surface of said mold, before the start of each casting operation, the lubricant devoid of liquified gas.

2. A method as recited in claim 1 wherein: said non-organic material is molybdenum disulfide.

3. A method as recited in claim 1 wherein: said non-organic material is lithium sulfide.

4. A method as recited in claim 1 wherein: said non-organic material is graphite.

5. A method as recited in any one of claims 1 to 4 wherein: said excluded organic compound is an oil.

6. A method as recited in claim 5 wherein: the excluded oil is a compound conventionally used as a mold lubricant in the continuous casting of molten steel.

7. A method as recited in any one of the preceding claims and further comprising:
providing a lubricant-containing layer atop the molten steel in said mold no earlier than when the mold has been at least partially filled with said molten steel;
maintaining said layer atop the molten steel substantially throughout the casting operation;
and osscillating said mold back and forth along the path of movement of said steel through said mold, said oscillation having a predetermined stroke length;

the thickness of said lubricant-containing layer being independent of the length of the stroke of the oscillating mold.

8. A method as recited in any one of the preceding claims wherein: said non-organic material is devoid of a liquified inert gas.

9. A method as recited in any one of the preceding claims wherein: said molten steel also contains tellurium in machinability increasing amounts.

10. A method as recited in claim 7 wherein: said lubricant-containing layer comprises a flux powder which is chemically and thermally relatively passive in the presence of molten steel containing lead and/or bismuth, under the conditions of continuous casting existing within the mold, to avoid explosions, and being incapable of producing a breakdown compound, under said conditions, which is explosive under said conditions.

Patentansprüche

1. Verfahren für den Senkrecht-Strangguß von Automatenstählen, die wenigstens eines der Elemente Bismut und Blei enthalten, wobei (a) besagter geschmolzener Stahl in eine Stranggußform mit einer Innenfläche eingebracht wird, (b) man besagten geschmolzenen Stahl zumindest teilweise in besagter Form erstarren läßt, damit er eine feste Außenhaut bildet, (c) besagte Innenfläche mit einem nicht-metallischen, nicht-organischen Formschmierstoff geschmiert wird, um das Anhaften besagter Außenhaut an besagter Innenfläche während des Gießens zu verhindern, (d) besagter Schmierstoff flüchtig aufgebracht wird, wobei der Schmierstoff sich während eines Gießvorganges abnutzt, (e) besagter Schmierstoff in Gegenwart von geschmolzenem Stahl, der Blei und/oder Bismut enthält, unter den innerhalb besagter Form auftretenden Bedingungen thermisch und chemisch relativ passiv ist, um Explosionen zu vermeiden, (f) besagter Schmeirstoff unter besagten Bedingungen nicht in der Lage ist, eine Abbauverbindung zu bilden, die unter besagten Bedingungen explosiv ist, und (g) von besagter Form jegliche organische Verbindung ausgeschlossen wird, die unter besagten Bedingungen Explosionen hervorruft; wobei besagtes Verfahren gekennzeichnet ist durch den Schritt, der folgendes umfaßt: Aufbringen des von verflüssigtem Gas freien Schmierstoffes direkt auf die Innenfläche besagter Form vor dem Beginn jedes Gießvorganges.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß besagtes nicht-organisches Material Molybdändisulfid ist.

3. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß besagtes nicht-organisches Material Lithiumsulfid ist.

4. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß besagtes nicht-organisches Material Graphit ist.

5. Verfahren nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß besagte ausgeschlossene organische Verbindung ein Öl ist.

6. Verfahren nach Anspruch 5, dadurch gekennzeichnet, daß das ausgeschlossene Öl eine Verbindung ist, die herkömmlicherweise als ein Formschmierstoff beim Stranggießen von geschmolzenem Stahl verwendet wird.

7. Verfahren nach einem der vorangehenden Ansprüche, weiter gekennzeichnet durch:
Aufbringen einer schmierstoffhaltigen Schicht oben auf den geschmolzenen Stahl in besagter Form, nicht früher als zu dem Zeitpunkt, an dem die Form zumindest teilweise mit besagtem geschmolzenen Stahl gefüllt worden ist;
Aufrechterhalten besagter Schicht oben auf dem geschmolzenen Stahl im wesentlichen während des gesamten Gießvorganges;
und Hin- und Herschwingen besagter Form entlang des Weges besagten Stahls durch besagte Form, wobei besagte Schwingung eine vorbestimmte Hublänge besitzt;
wobei die Dicke besagter schmierstoffhaltigen Schicht unabhängig ist von der Hublänge der schwingenden Form.

8. Verfahren nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß besagtes nicht-organisches Material frei von einem verflüssigtem Inertgas ist.

9. Verfahren nach einem der vorangehenden Ansprüche, dadurch gekennzeichnet, daß besagter geschmolzener Stahl auch Tellur in Mengen enthält, welche die maschinelle Bearbeitbarkeit erhöhen.

10. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß besagte schmierstoffhaltige Schicht ein Flußmittel umfaßt, das in Gegenwart von geschmolzenem Stahl, der Blei und/oder Bismut enthält, unter den Stranggußbedingungen, die innerhalb der Form auftreten, chemisch und thermisch relativ passiv ist, um Explosionen zu vermeiden, und nicht in der Lage ist, unter besagten Bedingungen eine Abbauverbindung zu bilden, die unter besagten Bedingungen explosiv ist.

Revendications

1. Procédé pour la coulée verticale continue d'aciers à usinage facile contenant au moins l'un des éléments bismuth et plomb, dans lequel (a) ledit acier en fusion est introduit dans un moule de coulée continue ayant une surface interne, (b) ledit acier en fusion est au moins partiellement solidifié dans ledit mou-

le pour former une enveloppe solide, (c) ladite surface interne est lubrifiée par un lubrifiant de moule non métallique non organique pour empêcher ladite enveloppe d'adhérer à ladite surface interne au cours de la coulée, (d) ledit lubrifiant est appliqué d'une manière transitoire selon laquelle le lubrifiant s'use au cours d'une opération de coulée, (e) ledit lubrifiant est thermiquement et chimiquement relativement passif, en présence d'un acier en fusion contenant du plomb et/ou du bismuth, dans les conditions existant à l'intérieur dudit moule, pour éviter les explosions, (f) ledit lubrifiant est incapable de produire un composé de dégradation, dans lesdites conditions, qui soit explosif dans lesdites conditions, et (g) il est exclu dudit moule tout composé organique produisant des explosions dans lesdites conditions, ledit procédé étant caractérisé par l'étape comprenant: l'application directement sur la surface interne dudit moule, avant le début de chaque opération de coulée, du lubrifiant dépourvu de gaz liquéfié.

2. Procédé selon la revendication 1, dans lequel ladite matière non organique est le disulfure de molybdène.

3. Procédé selon la revendication 1, dans lequel ladite matière non organique est le sulfure de lithium.

4. Procédé selon la revendication 1, dans lequel ladite matière non organique est le graphite.

5. Procédé selon l'une des revendications 1 à 4, dans lequel ledit composé organique exclu est une huile.

6. Procédé selon la revendication 5, dans lequel l'huile exclue est un composé utilisé de façon conventionnelle comme lubrifiant de moule dans la coulée continue de l'acier en fusion.

7. Procédé selon l'une des revendications précédentes et comprenant en outre:
le fait de prévoir une couche contenant un lubrifiant sur l'acier en fusion dans ledit moule pas avant que le moule ne soit au moins partiellement rempli par ledit acier en fusion,
le maintien de ladite couche sur l'acier en fusion sensiblement pendant toute l'opération de coulée,
et l'oscillation dudit moule dans la direction du mouvement dudit acier dans ledit moule, ladite oscillation ayant une longueur de course prédéterminée,
l'épaisseur de ladite couche contenant un lubrifiant étant indépendante de la longueur de la course du moule oscillant.

8. Procédé selon l'une des revendications précédentes, dans lequel ladite matière non organique est dépourvue de gaz inerte liquéfié.

9. Procédé selon l'une des revendications précédentes, dans lequel ledit acier en fusion contient aussi du tellure en des quantités améliorant l'usinabilité.

10. Procédé selon la revendication 7, dans lequel ladite couche contenant un lubrifiant comprend une poudre de fondant qui est chimiquement et thermiquement relativement passive en présence d'un acier en fusion contenant du plomb et/ou du bismuth, dans les conditions de coulée continue existant à l'intérieur du moule, pour éviter les explosions, et qui est incapable de produire un composé de dégradation, dans lesdites conditions, qui soit explosif dans lesdites conditions.