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D-8000 München 22(DE)(54) **Method for preventing mold explosions during continuous casting of free machining steels.**

(57) Molten steel containing lead and/or bismuth is continuously cast without explosions in the casting mold. The mold has sidewalls whose interior surface is coated with a non-organic lubricant which is not violently reactive thermally or chemically, under the conditions of continuous casting existing within the mold, to produce explosions, and does not breakdown under those conditions to produce a compound which is explosive under those conditions. Conventional petroleum-base lubricants for the continuous casting of molten steel are excluded.

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"METHOD FOR PREVENTING MOLD EXPLOSIONS DURING CONTINUOUS CASTING OF FREE MACHINING STEELS"

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 continuous casting operation, molten steel is flowed from a ladle into a intermediate container
 5 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
 10 dummy bar is withdrawn from the mold's downstream end, and the solidified shell containing unsolidified molten steel advances through the mold in a downstream direction, e.g. under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
 15 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.
 20 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, explosions occur within the mold when the mold is lubricated with
 25 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
 30 casting of molten steel containing bismuth.

Engeler, U.S. Patent No. 4,165,780 discloses a method for preventing mold explosions in the continuous casting of molten steel containing lead. 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,
 35 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. The Engeler method is relatively complicated and requires continuous monitoring.

A method in accordance with the present invention eliminates mold explosions during the continuous
 40 casting of molten steel containing bismuth or lead, without employing the complicated procedure described in Engeler. In accordance with the present invention, the interior surface of the continuous casting mold is lubricated, before the start of the cast, with a non-organic material (a) which acts as a lubricant on the mold surface, (b) which is not violently reactive thermally or chemically, under the conditions of continuous casting existing within the mold, to produce explosions and (c) which does not break down under those
 45 conditions to produce a compound which is explosive under those conditions. 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
 50 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 comprises:

providing a lubricant-containing layer atop the molten steel in said mold after but not before the mold has been at least partially filled with said molten steel;

maintaining said layer atop the molten steel substantially throughout the casting operation;
 oscillating said mold back and forth along the path of movement of said steel through said mold;
 said method being performed without relating the thickness of said lubricant-containing layer to the length
 of the stroke of the oscillating mold.

5 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 present
 in the molten steel, either with or without lead and/or bismuth.

In accordance with another aspect of the invention, in the continuous casting of molten steel containing
 at least one of the elements bismuth and lead in machinability increasing amounts, wherein said molten
 10 steel is introduced into a continuous casting mold having an interior surface lubricated with a mold lubricant
 during the cast, a method for reducing explosions within said mold, said method comprising:
 providing a lubricant-containing layer atop the molten steel in said mold after but not before the mold has
 been at least partially filled with said molten steel;
 maintaining said layer atop said molten steel substantially throughout the casting operation;
 15 excluding from said mold any organic compound which produces explosions under the conditions of
 continuous casting existing within said mold;
 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;
 said method being performed without relating to the thickness of said lubricant-containing layer to the
 20 length of the stroke of the oscillating mold.

The lubricant-containing layer may comprise a flux powder which 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 said
 conditions.

25 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
 30 examples of machinability increasing amounts for each of these ingredients are: 0.05-0.50 wt.% lead; 0.04-
 0.40 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
 casting mold having sidewalls with an interior surface coated with a lubricant in accordance with the present
 35 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
 40 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
 45 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
 50 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.

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	INGREDIENT	PARTS BY WEIGHT		
		A	B	C
5	SiO ₂	11	28	28
	Al ₂ O ₃	1	13	1.5
	MgO	0.5	1	0.1
10	CaO	11	23	3
	CaF ₂	40	12	16
	Na ₂ O	18	5	28
	B ₂ O ₃	16	0.4	1
15	C	0.2	6	0.3
	FeO	0.3	4	0.1
	P ₂ O ₅	--	--	12

20 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.

25 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.

30 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.

40 The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

45 The features disclosed in the foregoing description, in the claims and/or in the accompanying drawings may, both separately and in any combination thereof, be material for realizing the invention in diverse forms thereof.

Claims

- 50 1. In the continuous casting of molten steel containing at least one of the elements bismuth and lead in machinability increasing amounts, wherein said molten steel is introduced into a continuous casting mold having an interior surface lubricated with a mold lubricant during the cast, a method for reducing explosions within said mold, said method comprising:
- lubricating said interior surface of the continuous casting mold, before the start of the cast, with a non-metallic, non-organic material (a) which acts as a lubricant on said surface, (b) which is not violently reactive
- 55 thermally or chemically, under the conditions of continuous casting existing within said mold, to produce

explosions, and (c) which does not break down under said conditions to produce a compound which is explosive under said conditions;

and excluding from said mold any organic compound which produces explosions under said conditions.

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

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

4. A method as recited in claim 1 wherein: said non-organic 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
10 mold lubricant in the continuous casting of molten steel.

7. A method as recited in any one of the preceding claims and comprising:

providing a lubricant-containing layer atop the molten steel in said mold after but not before the mold has been at least partially filled with said molten steel;

maintaining said layer atop the molten steel substantially throughout the casting operation;

15 oscillating said mold back and forth along the path of movement of said steel through said mold;

said method being performed without relating the thickness of said lubricant-containing layer to the length of the stroke of the oscillating mold.

8. A method as recited in any of the preceding claims wherein:

said non-organic compound is devoid of a liquified inert gas.

20 9. A method as recited in any of the preceding claims wherein:

said molten steel also contains tellurium in machinability increasing amounts.

10. In the continuous casting of molten steel containing at least one of the elements bismuth and lead in machinability increasing amounts, wherein said molten steel is introduced into a continuous casting mold having an interior surface lubricated with a mold lubricant during the cast, a method for reducing explosions
25 within said mold, said method comprising:

providing a lubricant-containing layer atop the molten steel in said mold after but not before the mold has been at least partially filled with said molten steel;

maintaining said layer atop said molten steel substantially throughout the casting operation;

30 excluding from said mold any organic compound which produces explosions under the conditions of continuous casting existing within said mold;

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;

said method being performed without relating the thickness of said lubricant-containing layer to the length of the stroke of the oscillating mold.

35 11. A method as recited in any one of claims 7 to 10 wherein:

said lubricant-containing layer comprises a flux powder which 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
40 conditions.

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