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

(11) EP 1 872 884 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.01.2008 Bulletin 2008/01

(51) Int Cl.:
B22D 11/22 *(2006.01)* ***B22D 11/124*** *(2006.01)*

(21) Application number: **06013581.1**

(22) Date of filing: **30.06.2006**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

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(54) **Method of improving the performance of a continous casting device for casting slabs of metal and casting device**

(57) In a method of operating a continuous casting device (10) for casting slabs, the device (10) comprising a cooling chamber (14) for cooling a ca slab, the following steps are carried out:
a) adjusting the casting rate to a predetermined value,
b) adjusting the cooling capacity of the cooling chamber (14),

wherein step b) comprises controlling the amount of air laden with water vapour removed from the cooling chamber (14).

The invention also relates to a device (10) for continuous casting a steel slab.

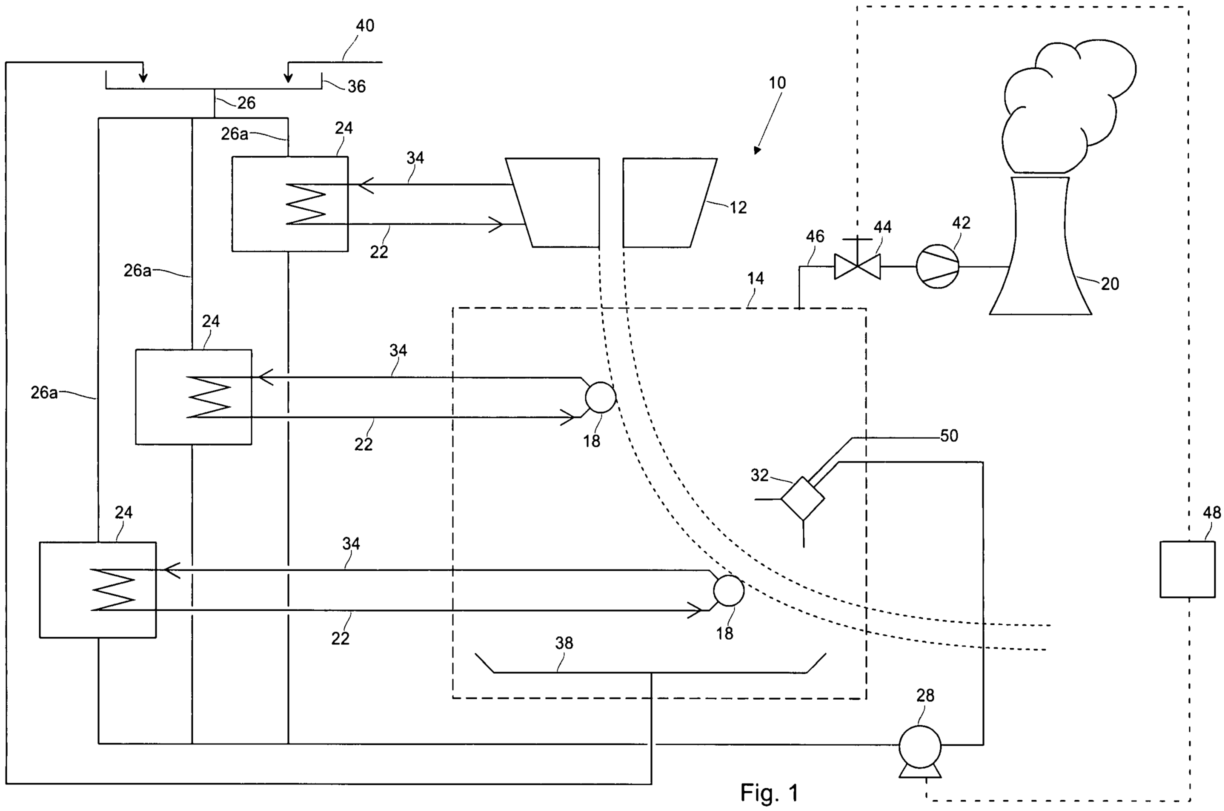

Fig. 1

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Description

[0001] The present invention relates to a continuous casting process, as well as a device for continuously casting steel slabs.

[0002] Continuous casting of steel slabs is a well known process in the art. In such a process molten metal is poured in a casting mold having an outlet opening in its bottom. At the start of the process the molten metal is caused to adhere to a dummy bar initially filling the outlet opening. This dummy bar is withdrawn at a constant speed in order to form a continuously growing slab having a solidified skin or shell. This skin holds the still liquid core. Below the mold the slab is guided over a conveyor system and cooled in a cooling chamber - also known as a secondary cooling box - adjacent the mold. This allows control of the surface temperature of the casted product. Usually cooling is performed in several cooling zones. The conveying system comprises guide rolls and driven rolls for withdrawal of the casted product. Cooling of the casted slab is mainly achieved by applying cooling water from water nozzles or nozzles for a mix of water and atomizing air, onto the casted product. See e.g. "The book of steel", Eds. Béranger and Henry, 1996, p. 1194-1195 and "The Making, Shaping and Treating of Steel", Eds. Lankford et al., 1984, 10th ed., p. 746. Furthermore the casting device components contacting the slab like the guide and driven rolls are cooled themselves internally using a closed circuit thereby also contributing to some extent to the cooling of the slab. The dummy bar is removed, and the continuously growing slab is cut into sections having a predetermined length. These sections can be individually processed, e.g. in a hot rolling mill.

[0003] Usually the casting speed is set to a specified value depending on the device specifications, steel composition, required steel quality specifications and the like. Typical casting speeds are in the order of magnitude of metres per minute, ranging e.g. from less than one to several metres per minute. However, some product specifications allow to increase the casting speed. If the casting speed is increased, the cooling regime has to be adjusted. In the art cooling is increased by increasing the volume of water sprayed per unit of slab area and unit of time. However, the cooling rate offered by the water sprays may become insufficient for certain allowable casting speeds. This is usually recognized by an increase of the temperature of the water in the closed circuit cooling of the casting device components contacting the slab. Such a temperature increase is detrimental as it may cause damage to these components or parts thereof like bearings. In such a situation the casting speed needs to be reduced to a value, where no overheating of the components occurs. This is an economic disadvantage in view of operation of the casting device. Thus cooling may be a limiting factor in view of production rate increase.

[0004] Furthermore during a production run it may happen that a part of a subsequent processing device in a direct rolling operation e.g. a roll of a hot rolling mill needs to be serviced. In such a case the casting speed has to be reduced temporarily but not stopped, until the service or maintenance work has been finished. Theoretically, a reduction to almost zero would be beneficial, but the required simultaneously reduction of the cooling unit can not be achieved, because by drastically reducing the volume of water the spray profile of water defining the cooling profile of the temperature of the casted slab is distorted seriously. When the cooling performance should be maintained at a substantial level, the (thin) slab might be solidified too much before it has reached the horizontal part of the machine. A similar situation requiring a substantial reduction of casting speed, might occur due to a failure in the device upstream of the cooling section, e.g. a temporary lack of supply of molten metal to be casted. Then again cooling may be a limiting factor.

[0005] An object of the invention is to provide a method of operating a casting device, which offers an increased flexibility towards operation, in particular with respect to casting speed.

[0006] Another object of the invention is to improve the performance of a casting device.

[0007] A further object of the invention is to provide a casting device wherein the disadvantages mentioned above do not occur or to a lesser extent.

[0008] Still another object of the invention is to improve the safe operation of a casting device.

[0009] According to a first aspect of the invention a method of operating a continuous casting device for casting slabs is provided wherein the casting device comprises a cooling chamber for cooling a casted slab, which method comprises the steps of

a) adjusting a casting rate to a predetermined value,
b) adjusting the cooling capacity of the cooling chamber to a predetermined level,

wherein step b) comprises controlling the amount of air laden with water vapour removed from the cooling chamber.

[0010] In the method according to the invention a casting device is operated by setting a predetermined casting speed together with adjustment of the cooling regime to this speed. In contrast to or in addition to the typical prior art methods the cooling capacity of the cooling chamber is tuned to the set casting speed of the steel slabs by controlling the quantity of air withdrawn from the cooling chamber. As will become apparent from the following detailed discussion this controlling step offers a very effective way to improve the operation of a casting device, in other words an improved method of casting slabs.

[0011] In a casting device heat needs to be transferred away from the solidifying slab. As already explained hereinbefore, a part of this required heat transfer is brought about by the closed circuit cooling. However, this kind of heat transfer is difficult to adjust to the required cooling and therefore not useful as a control means. Moreover, the potential range of adjustment is narrow and the effect on operation is restricted. In the open cooling using the water sprays, heat transfer may become difficult as well. In the open cooling system heat transfer has two components, that is to say heat required for heating up the sprayed water and evaporation. Evaporation is far more effective because it requires more enthalpy than only heating up. For example raising the temperature of water from 20°C to 80°C requires about 250 kJ/kg, while evaporation at 80°C will take approximately 2300 kJ/kg. However, evaporation may become hampered when the water temperature is increased to about 70-80°C by a film boiling phenomenon. This phenomenon means that at a sufficiently high temperature of the water a film is formed on the surface of the slab reducing the heat flux substantially. Thus there is a serious limitation to cooling by the water sprays.

[0012] In the method according to the invention cooling is controlled by adjusting the quantity of air laden with water vapour that is removed from the cooling chamber. Usually cooling is performed in a cooling chamber wherein the pressure is kept slightly below the ambient pressure. This prevents that escaping vapour could hamper operations on the casting platform. Air in the cooling chamber is replenished by ambient air leaking into the cooling chamber. Evaporation at temperatures lower than 100°C is only possible as long as the absolute pressure is not higher than the partial vapour pressure. In other words, evaporation may occur if the water temperature is higher than the saturation temperature at the existing partial vapour pressure. However, if the partial vapour pressure increases, the saturation temperature increases, requiring a higher water temperature otherwise no evaporation can take place. But at some stage the phenomenon of film boiling will become prevailing, thereby further limiting an increase of the heat transfer from the hot slab to the water. Now the method according to the invention allows to further increase cooling by removing more air containing water vapour, thereby keeping the partial vapour pressure at a relatively low level and consequently the saturation temperature also at a low level. Similarly, cooling can be suppressed by decreasing the flow of exhaust air from the cooling chamber. Thus, in general the invention provides an effective way of operating a cooling chamber of a casting device in view of a desirable casting speed and its associated cooling rate of the steel slab.

[0013] With respect to the casting methods and devices as known from the state of the art the implementation of the present method requires an addition of a control means for the fan typically present in the exhaust of the cooling chamber. Previously, this fan was set once at a predetermined value upon installation. Due to its height position in the exhaust usually the fan is not accessible for manual control and/or adjustment. Direct control of the rotational speed of the fan is an option. With a view to increasing the cooling capacity the existing fan might be exchanged for a controlled fan having a larger capacity. Another embodiment comprises a fixed speed fan with a flow controller such as a controllable (throttle) valve.

[0014] Advantageously the method according to the invention also involves controlling the amount of water sprayed onto the casted slab. This embodiment is advantageous as it provides double means for controlling cooling, i.e. by the amount of air laden with vapour removed from the cooling chamber as well as by the amount of water introduced into the chamber. The largest flexibility and/or accuracy of operating a casting device is achieved when both amounts are controlled simultaneously.

[0015] The method according to the invention is particularly useful for dealing with casting situations where temporarily casting speed is to be reduced. Accordingly, a useful embodiment comprises the situation, where in step a) the casting rate is reduced and in step b) the quantity of air discharged is reduced. This embodiment ensures the safe and continuous operation of a casting device, even if the casting speed has to be reduced substantially.

[0016] In a variant the method according to the invention is applied for increasing the production rate. Accordingly, an alternative embodiment is directed to the situation,
wherein step a) comprises an increase of the casting rate and step b) comprises an increase of the quantity of air discharged. Preferably, the amount of water sprayed onto the casted slab is controlled as well.

[0017] In some casting devices a heat exchange occurs between the hot return conduit of the closed circuit cooling and the water to be fed to the water spray nozzles. As a result of this heat exchange this water is relatively warm compared to cold water directly passed to the spray nozzles, the sensitivity of such casting devices for non-standard situations is high. It is advantageous to use the method according to the invention in such casting devices.

[0018] The invention also relates to a casting device for continuous casting slabs, comprising
a casting mold,
a cooling chamber for solidifying a casting slab comprising a conveying means for conveying a casted slab through the cooling chamber,
the cooling chamber being provided with a cooling water supply system for applying cooling water to the slab, and an air outlet for discharging air laden with water vapour from the cooling chamber,
wherein the casting device comprises control means for controlling the quantity of air discharged.

[0019] In the casting device according to the invention the control means allow for an active intervention in the amount of air that is removed from the cooling chamber. The casting device according to the invention offers advantages similar to the beneficial effects described above with respect to the method of the invention. Advantageously the conveying means are provided with cooling means as well.

[0020] In an embodiment of the casting device according to the invention a flow controller such as a (throttle) valve is provided in the exhaust the flow controller being controllable by the control means. In such a situation means for forcibly withdrawing air such as a fan may operate at a constant speed. It will be understood that such a valve can be dispensed with when the speed of the fan is directly adjustable.

[0021] The invention is illustrated in more detail in view of the attached drawing,
wherein the sole figure is a schematic representation of an embodiment of a casting device according to the invention.

[0022] The casting device is generally indicated by reference numeral 10, comprising inter alia a casting mold 12 and a cooling chamber 14 (represented by a dashed line) below the casting mold 12. In the cooling chamber 14 a conveyor system is provided for withdrawal and guidance of a solidifying slab from the mold 12. In this fig. this conveyor system is exemplified by driven rolls 18. Downstream of the cooling chamber 14 the solidified slab is cut into suitably sized semi products. The cooling chamber 14 is also provided with an exhaust 20 for removing air. The casting mold 12 and separate driven rolls 18 each have an internally closed cooling circuit 22. Each circuit 22 is connected to a heat exchanger 24 where water supplied by conduit 26 to lines 26a and to be fed by a pump 28 via conduit 30 to spray nozzle 32 is in heat exchanging contact with the return conduit 34 of circuit 22. Water is supplied from a tank 36. Spray nozzle 32 may also be provided with atomizing air. A drain 38 provided at the bottom of cooling chamber 14 returns excess water back to tank 36 (e.g. from a cooling tower), to which also make up water can be added through conduit 40. According to the invention the amount of air laden with water vapour removed from the cooling chamber 14 and discharged to the atmosphere via stack 20 is controlled. In this embodiment a fan 42 operating at a fixed speed withdraws the air from the cooling chamber. Furthermore a throttle valve 44 is mounted in a conduit 46 connecting the cooling chamber 14 to the stack 20. This throttle valve 44 is actuated by controller 48, which also controls the pump 28.

[0023] The spray nozzle 32 may also be directly fed with "cold" water, e.g. via a separate supply line 50, e.g. from tank 36 or other source. In that situation, the water heat exchanged in heat exchangers 24 is usually not used by the nozzle 32, but instead thereof returned to tank 36 (e.g. a cooling tower).

Claims

1. Method of operating a continuous casting device (10) for casting slabs, the casting device comprising a cooling chamber (14) for cooling a casted slab, which method comprises the steps of

   a) adjusting the casting rate to a predetermined value,
   b) adjusting the cooling capacity of the cooling chamber (14),

   wherein step b) comprises controlling the amount of air laden with water vapour removed from the cooling chamber (14).

2. Method according to claim 1, wherein step b) also comprises controlling the amount of water sprayed onto the casted slab.

3. Method according to claim 2, wherein the amount of air laden with water vapour and the amount of water sprayed onto the casted slab are controlled simultaneously.

4. Method according to one of the preceding claims, wherein in step a) the casting rate is reduced and in step b) the quantity of air discharged is reduced.

5. Method according to one of the preceding claims 1-4, wherein step a) comprises an increase of the casting rate and step b) comprises an increase of the quantity of air discharged.

6. Casting device (10) for continuous casting steel slabs, comprising
   a casting mold (12),
   a cooling chamber (14) for solidifying a casting slab comprising a conveying means (16) for conveying a slab through the cooling chamber (14),
   the cooling chamber (14) being provided with a cooling water supply system (26, 26a, 28, 32, 36) for applying cooling water to the slab, and an air outlet (20, 46) for discharging of air laden with water vapor from the cooling chamber (14),
   wherein the casting device also comprises control means (48) for controlling the quantity of air discharged.

7. Casting device according to claim 6, wherein the air outlet (20, 46) is provided with air discharge means (42) for forcibly withdrawing air, which is controlled by said control means (48).

8. Casting device according to claim 7, wherein the air discharge means comprise a fan (42).

9. Casting device according to one of the preceding claims 7 and 8, wherein the air discharge means also comprise a throttle valve (44).

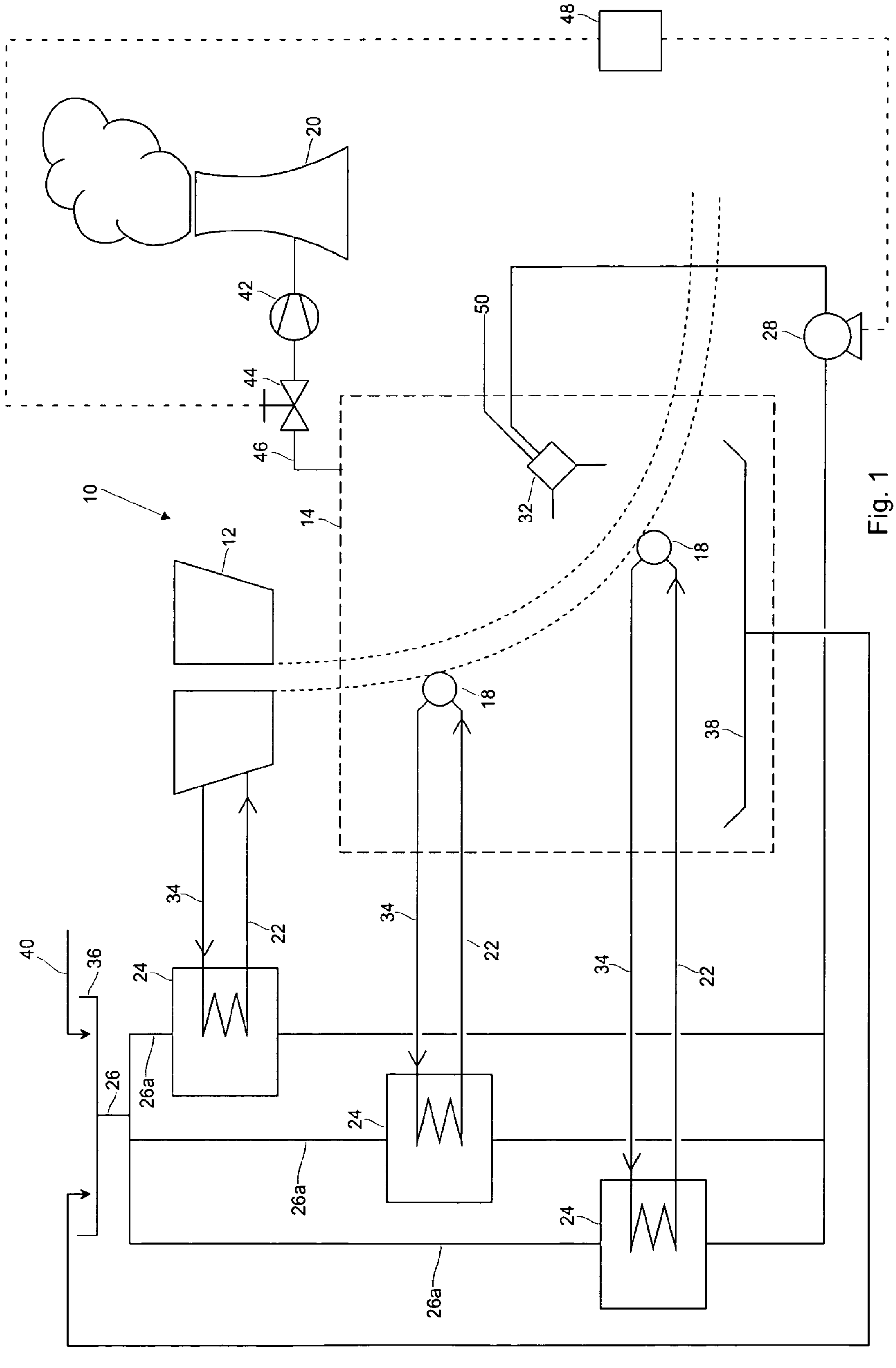
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Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 06 01 3581

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X	* page 7 - page 10 *	4,5	
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TECHNICAL FIELDS SEARCHED (IPC)

B22D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	10 January 2007	Scheid, Michael

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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