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(54) **Process for the continuous casting of molten steel to form high-quality billets or blooms**

(57) Process for the continuous casting of a molten steel to form high-quality billets or blooms, utilizing a device of the type comprising a buffer tank, an immersion pipe, a casting mould, and a line for feeding the molten metal to the buffer tank, the immersion pipe being connected to the bottom of the buffer tank and, during operation, extending as far as into the casting mould, the buffer tank being designed so that it can be closed off in a gastight manner and being provided in or in the vicinity of its top wall with a suction opening, and the feedline opening into the buffer tank in the vicinity of its bottom, while the other end of the feedline is connected to the bottom of a tundish, which bottom lies at a higher level than that of the buffer tank, and means being present for injecting a flush gas into the molten steel at the location of the feedline, in which method argon is injected as the flush gas, and gas is extracted from the buffer tank via the suction opening until an absolute gas pressure of < 15 mbar is established in the top of the said buffer tank, and argon is injected in a volume of > 25 l STP (volume at standard temperature of 0°C and standard pressure of 1 atmosphere) per tonne of cast steel.

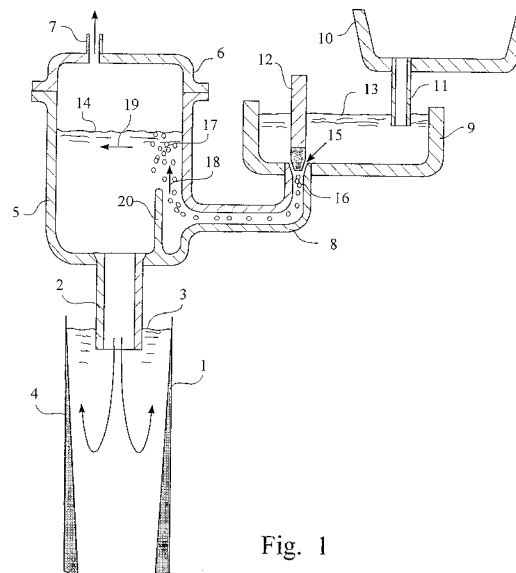


Fig. 1

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Description

[0001] The invention relates to a process for the continuous casting of molten steel to form high-quality billets or blooms, utilizing a device of the type comprising a buffer tank, an immersion pipe, a casting mould, and a line for feeding the molten metal to the buffer tank, the immersion pipe being connected to the bottom of the buffer tank and, during operation, extending as far as into the casting mould, the buffer tank being designed so that it can be closed off in a gastight manner and being provided in or in the vicinity of its top wall with a suction opening, and the feedline opening into the buffer tank in the vicinity of its bottom, while the other end of the feedline is connected to the bottom of a tundish, which bottom lies at a higher level than that of the buffer tank, and means being present for injecting a flush gas into the molten steel at the location of the feedline.

[0002] A device of the type mentioned in the preamble has already been described in Dutch patent NL 1001976 for use in the casting of slabs. The aim of this device is to counteract the formation of cracks and oxide inclusions, which are often relatively large inclusions, by flushing with a flush gas. To achieve this, the injection of small volumes of, for example, argon is sufficient, consideration being given, for example, to less than 5 l (s.t.p.) per tonne of cast steel. Therefore, depending on the geometry of the casting installation and the immersion pipe, the operating pressure must not be too low. For this known application, the operating pressure will generally have to be approx. 100 mbar or higher.

[0003] In the case of slab-casting machines, casting is often carried out using steel which has been degassed in advance, the degassing being carried out, for example, with the aid of a vacuum pan treatment. It is also known to remove, for example, hydrogen from the cast slabs in annealing furnaces.

[0004] In the case of billet-casting machines, the use of vacuum pan installations and annealing furnaces is not an attractive option owing to the smaller scale of the production facilities. Therefore, there is a need for other possible ways of counteracting the concentration of hydrogen in the liquid steel. In this context, it should be noted that, for example when casting forged billets, it is particularly important to reduce the concentration of hydrogen in the liquid steel in order to:

- counteract hydrogen embrittlement in forged steel. Particularly when the final dimensions after forging are very close to the cast dimensions, scarcely any deformation takes place in order to remove the hydrogen. The stresses in these components (which are often critical from the point of view of safety aspects, for example in the automotive industry) are such that hydrogen embrittlement (at the grain boundaries), may easily lead to cracks and fracture without there being any possibility of measuring this by ultrasound in the forged product (delayed crack-

ing).

- counteract gas bubbles (pinholes). These gas bubbles are formed because solidified steel is able to contain less gas than liquid steel.

[0005] The use of the device which is known from NL 1001976 in the manner described above does not provide adequate results when casting billets and blooms if it is desired to achieve very low hydrogen concentrations.

[0006] An advantage of very low hydrogen concentrations in, for example, steel which is subject to considerable deformation consists in the fact that such concentrations prevent the formation of hydrogen-filled cavities in the solidifying steel.

[0007] Therefore, the invention consists in the fact that, in the method of the type which is known according to the preamble, argon is injected as the flush gas and that gas is extracted from the buffer tank via the suction opening until an absolute gas pressure of < 15 mbar is established in the top of the said buffer tank, and that argon is injected in a volume of > 25 l (s.t.p.) per tonne of cast steel.

[0008] It should be noted that this gas pressure and this volume differ considerably from the levels which are customary when casting slabs.

[0009] By injecting flush gas, such as argon, into the molten metal at the location of the feedline, gas bubbles which have a relatively long residence time in the bath between the injection location and the free surface of the metal in the tundish can form in this feedline. As these gas bubbles rise upwards, the pressure on them will be reduced and the gas bubbles will acquire a larger interface with the metal.

[0010] The bubbles of argon gas have two functions. Firstly, the gas bubbles form nuclei for the formation of hydrogen bubbles, with the result that hydrogen is diffused out of the molten metal more quickly, and secondly the argon gas absorbs hydrogen inside the bubbles.

[0011] To achieve successful degassing, it is recommended to position the means for injecting the flush gas at the location where the feedline is connected to the tundish. This makes the residence time of the bubbles of argon gas as long as possible. According to the invention, it is possible to achieve hydrogen concentrations which may be as low as approx. 2 ppm if an absolute gas pressure in the buffer tank of < 15 mbar is established and if argon is injected in a volume of > 25 l (s.t.p.) of cast steel.

[0012] Particularly good results can be obtained if the absolute gas pressure in the buffer tank is < 10 mbar, and if more than 33 l (s.t.p.) of argon is injected per tonne of cast steel.

[0013] Finally, the residence time of the argon gas bubbles in the molten steel can be increased still further, thus allowing further improved removal of hydrogen from the steel, if the argon injected brings about a flow of the steel along the surface of the bath. This can be

achieved, for example, by causing the gas bubbles to rise upwards in the buffer tank in the vicinity of a wall which is at a distance from the location where the immersion pipe is connected to the bottom of the buffer tank.

[0014] The invention will now be explained with reference to a figure.

[0015] This figure diagrammatically depicts part of a device for the continuous casting of steel. In order to allow the invention to be clearly understood, various components are not to scale.

[0016] Reference numeral 1 indicates, on an enlarged scale, the inner wall of a casting mould for casting steel billets. An immersion pipe 2 for supplying molten steel extends to below the level 3 of the steel in the casting mould.

[0017] The casting mould is intensively cooled (not shown), with the result that a solidified shell 4 is formed, the thickness of which increases in the downwards direction. On leaving the casting mould, this solidified shell 4 has to be sufficiently strong to be able to be withdrawn further using mechanical means without it rupturing. The means for withdrawing the billet which is formed in this way are not shown, but are in the form of a traditional set of rollers such as that which is depicted, by way of example, in German Laid-Open Specification 2,017,469. In order to be able to carry out casting at a relatively high speed, it is necessary to control the flow of the molten steel without imposing an excessive casting impulse on the solidified shell, which is still soft, since this could lead to this solidified shell being fractured. Preferably, therefore, the immersion pipe is connected to a buffer tank 5, which is closed off with the aid of a cover 6, and a vacuum can be created, via the suction opening 7, above the molten steel which is situated in the buffer tank 5.

[0018] On the one hand, the presence of a buffer tank makes the flow of molten steel to and through the immersion pipe 2 more regular, while furthermore, as a result of the reduced gas pressure above the molten steel, the ferrostatic pressure in the immersion pipe is reduced.

[0019] Molten steel is fed to the buffer tank 5 through the feedline 8, which is for its part connected to a tundish 9. This tundish 9 is able to ensure that there is a constant flow of steel to the buffer tank 5, even if the molten steel is supplied from the steel factory in batches via steel ladles 10. Steel ladle 10 is for its part emptied into tundish 9 via a casting pipe 11. With the aid of a stopper rod 12, the flow of steel from the tundish 9 can be regulated in order to compensate for differences in the level 13 of the steel in the tundish. The stopper rod 12 can also be used, if desired, to shut off the flow from the tundish entirely. It is necessary to seek to ensure that the level 14 in the buffer tank 5 remains as stationary as possible, so that the casting conditions remain uniform. Argon gas is injected at location 15 and forms bubbles 16 which are entrained to the buffer tank 5 by the stream

of molten steel running through the feedline 8. In the buffer tank 5, these bubbles form a screen 17 of bubbles which rises upwards, in the direction of arrow 18, towards the surface of the bath. In so doing, the stream 17 of bubbles causes the steel to flow along the surface of the bath in the direction of arrow 19.

[0020] Owing to the presence of the projection 20, the stream of bubbles is additionally diverted in the upwards direction. This also prevents gas bubbles from being entrained into the casting mould by the flow of liquid steel. A simple projection made of refractory material and with a height of approximately 10 cm is sufficient to achieve this effect.

[0021] While they are moving through feedline 8 and via the screen 17 of bubbles, the bubbles 16 grow, initially by taking up hydrogen and then as a result of the ferrostatic pressure on these rising bubbles being reduced. As a result, the surface area of the bubbles is increased to such an extent that hydrogen can be absorbed very intensively into the argon bubbles. Then, at the surface of the bath, the hydrogen which is released is extracted via suction opening 7.

[0022] In a practical situation, steel was cast at a rate of 0.3 t/min. The temperature of the cast steel was 1500°C. In the steel ladle 10, a hydrogen concentration of 6 ppm was detected. With a surface area of the steel melt in the tundish of approximately 1 m², an absolute pressure of 10 mbar was maintained above the steel surface 14. A hollow stopper rod 12 was used, and a volume of argon gas of 10 l (s.t.p.)/min was injected into the feedline 8 at the seal of the stopper rod. It was found that the argon bubbles formed in the screen 17 of bubbles grew to a diameter of approximately 10 mm.

[0023] When measurements were carried out, it was found that the hydrogen content in the cast steel had been reduced from 6 ppm to between 1 and 2 ppm.

[0024] Without injecting argon, but under conditions which were otherwise identical, measurements showed that the cast steel had a hydrogen content of between 4 and 5 ppm.

[0025] It should be noted that the novel process also allows other components which are naturally gaseous to be removed from the steel which is to be cast.

Claims

1. Process for the continuous casting of molten steel to form high-quality billets or blooms, utilizing a device of the type comprising a buffer tank (5), an immersion pipe (2), a casting mould (1), and a line (8) for feeding the molten metal to the buffer tank (5), the immersion pipe (2) being connected to the bottom of the buffer tank (5) and, during operation, extending as far as into the casting mould (1), the buffer tank (5) being designed so that it can be closed off in a gastight manner and being provided in or in the vicinity of its top wall (6) with a suction opening

(7), and the feedline (8) opening into the buffer tank (5) in the vicinity of its bottom, while the other end of the feedline (8) is connected to the bottom of a tundish (9), which bottom lies at a higher level than that of the buffer tank (5), and means (15) being present for injecting a flush gas into the molten steel at the location of the feedline (8), characterized in that argon is injected into the stream of liquid steel as the flush gas, and in that gas is extracted from the buffer tank via the suction opening (7) until an absolute gas pressure of < 15 mbar is established in the top of the said buffer tank, and in that argon is injected in a volume of > 25 l (s.t.p.) per tonne of cast steel.

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2. Process according to Claim 1, characterized in that the absolute gas pressure in the top of the buffer tank (5) is < 10 mbar, and in that more than 33 l (s.t.p.) of argon is injected per tonne of cast steel.

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3. Process according to one of Claims 1-2, characterized in that the argon injected brings about a flow of the steel along the surface of the bath.

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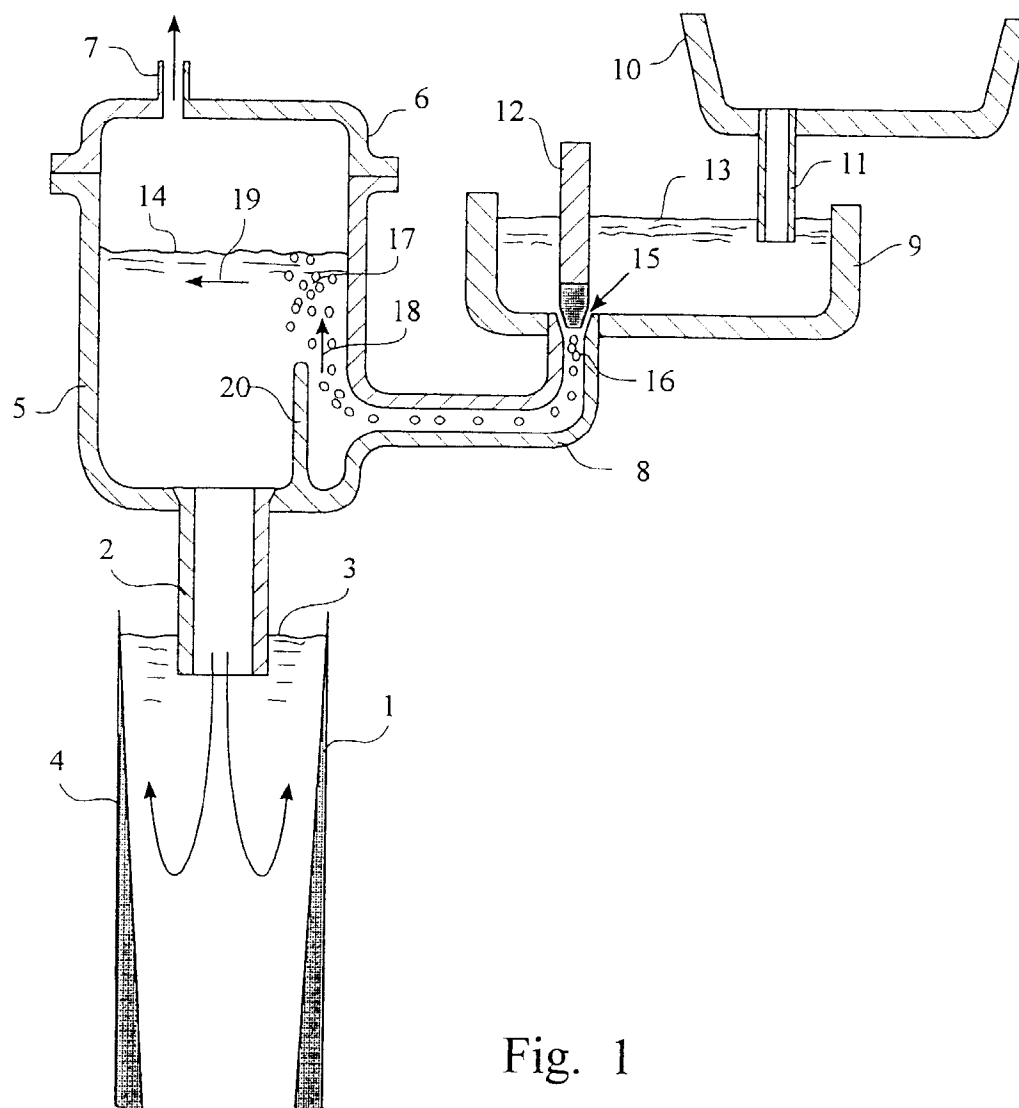


Fig. 1



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EUROPEAN SEARCH REPORT

Application Number
EP 98 20 3947

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	NL 1 001 976 C (HOOGOVENS GROEP BV) 24 June 1997 * page 10, line 4 - page 11, line 26; figure 1 *	1	B22D11/10
A	----- PATENT ABSTRACTS OF JAPAN vol. 007, no. 116 (M-216), 20 May 1983 & JP 58 035051 A (KAWASAKI SEITETSU KK), 1 March 1983 * abstract *	1	
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A	----- DE 20 17 469 A (VOEST AG) 22 October 1970 * figures 1-8 *	1	
A	----- FR 2 675 411 A (SIDERURGIE FSE INST RECH) 23 October 1992 * figures 2,4 *	1	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Place of search THE HAGUE			Date of completion of the search 10 March 1999
Examiner Mailliard, A			
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 98 20 3947

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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