US 20080164003A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2008/0164003 A1

Kempken et al. (43) Pub. Date: Jul. 10, 2008

(54) METHOD AND INSTALLATION FOR PRODUCING LIGHT GAUGE STEEL WITH A HIGH MANGANESE CONTENT

(76) Inventors: **Jens Kempken**, Kaarst (DE); **Markus Reifferscheid**, Korschenbroich (DE); **Albrecht Girgensohn**, Dusseldorf (DE)

Correspondence Address:
FRIEDRICH KUEFFNER
317 MADISON AVENUE, SUITE 910
NEW YORK, NY 10017

(21) Appl. No.: **11/666,535**

(22) PCT Filed: **Mar. 3, 2006**

(86) PCT No.: **PCT/EP2006/001954**

§ 371 (c)(1),
(2), (4) Date: **Apr. 27, 2007**

(30) **Foreign Application Priority Data**

Mar. 5, 2005 (DE) 10 2005 010 243.3

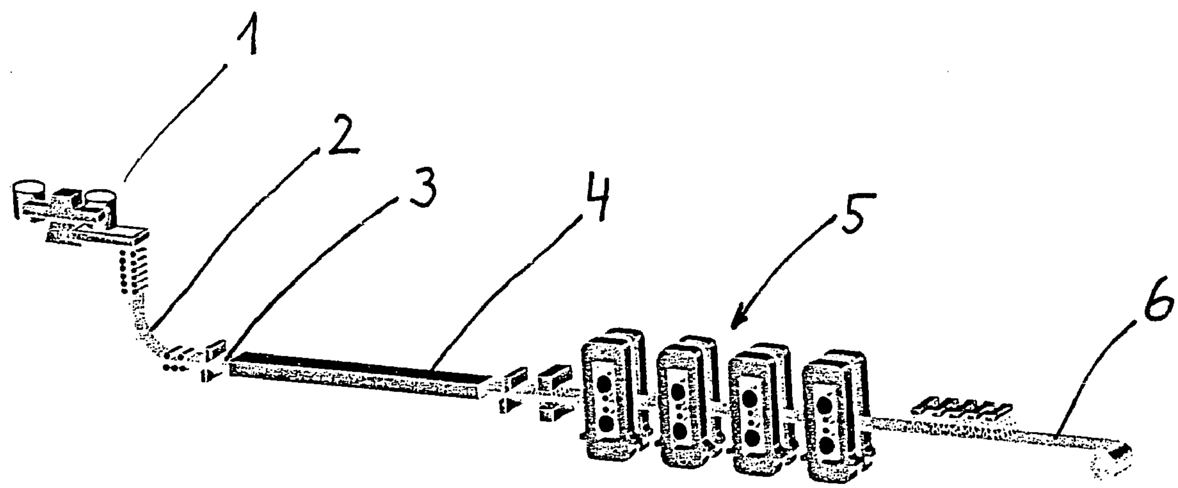
Publication Classification

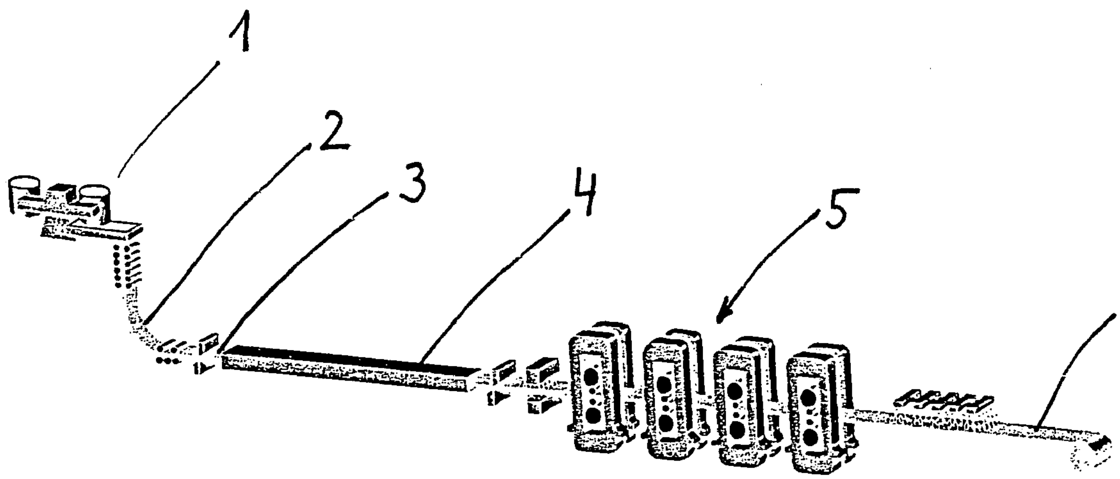
(51) **Int. Cl.**
B22D 11/126 (2006.01)
B22D 11/00 (2006.01)

(52) **U.S. Cl.** **164/460**; 164/418

(57) **ABSTRACT**

The production of steels with high contents of manganese (Mn), aluminum (Al), and silicon (Si) with TWIP properties (Twinning-Induced Plasticity) by continuous casting is considered difficult or impossible in the present state of the art for various reasons. These reasons include low strength of the strand shell during solidification due to intense microsegregation of Mn, high strength at relatively low temperatures, reactions of the aluminum in the steel with the flux powder, macrosegregation, depletion of the alloying elements near the surface, and oxidation of the grain boundaries during the reheating of slabs in the pusher furnace. Therefore, in accordance with the invention, successively arranged process steps are used to cast light gauge steel with a given chemical composition of 15-27% Mn, 1-6% Al, 1-6% Si, ≦0.8% C, with the remainder consisting of Fe and accompanying impurity elements on a thin-slab casting machine (**1**) (d≦120 mm) with the use of suitable flux powders, to cut slabs (**3**) from the endless strand (**2**) immediately after solidification, to bring about temperature equalization in a continuous-type intermediate furnace (**4**), and then to hot roll the slab (**3**) immediately without intermediate cooling.




1
2
3
4
5
6

METHOD AND INSTALLATION FOR PRODUCING LIGHT GAUGE STEEL WITH A HIGH MANGANESE CONTENT

[0001] The invention concerns a method and an installation for producing hot-rolled strip from a highly cold-workable, high-strength, austenitic light gauge steel with increased contents of manganese (Mn), aluminum (Al), and silicon (Si) with TWIP properties (Twinning-Induced Plasticity), wherein the steel is first cast into an endless strand in a continuous casting installation, cut into slabs, and then rolled to the final thickness.

[0002] Austenitic light gauge steels with TWIP properties for use, e.g., in automobile body parts, reinforcing automobile body members, and cryogenic tanks and pipelines have, for example, according to EP 0 889 144 B1, a chemical composition of 10-30% Mn, 1-6% Si, 1-8% Al (with Si+Al≦12%), with the remainder consisting of Fe.

[0003] DE 199 00 199 A1 discloses a high-strength light gauge steel with 7-30% Mn, 1-10% Al, 0.7-4% Si, ≦10% Cr, ≦10% Ni, ≦3% Cu, ≦0.5% C, and optionally with the additional alloying elements N, Va, Nb, Ti, and P, which has not only good mechanical properties but also good resistance to corrosion and stress-corrosion cracking. This steel is intended to be cast by continuous casting and hot rolled or to be cast by thin-strip casting with near-net shape.

[0004] The production of high-manganese steels by continuous casting is considered difficult or impossible in the present state of the art for various reasons, namely, low strength of the strand shell during solidification due to intense microsegregation of Mn (danger of breakout at Mn>15%), high strength at relatively low temperatures (installation overloading, cracking problems), reactions of the aluminum in the steel with the flux powder (limitation of function), macrosegregation, hydrogen and/or oxygen absorption by spray water cooling, increased occurrence of nonmetallic inclusions, depletion of the alloying elements near the surface, and oxidation of the grain boundaries during the reheating of slabs in the pusher furnace.

[0005] In a publication by Spitzer et al.: "Innovative Steel Products—Challenge for Process Development"; Conference Report: Barbara 2001, pp. 71-84, it is stated in this regard that steels with increasing manganese contents are increasingly difficult to cast. For one thing, they have low strength at high temperatures after solidification, since at high manganese contents, manganese becomes highly concentrated in the residual melt and lowers the melting point in the interdendritic regions. This increases the tendency towards sticking-type breakouts, which make continuous casting impossible at Mn contents of 15% or more according to present estimates. On the other hand, the steels have high strength at low temperatures, so that installation overloading occurs during the bending of the steel, and cracking must be expected. In addition, at aluminum contents of several percent, which are used in these steels for the purpose, among others, of reducing the density, reactions occur with the flux powder, which have serious adverse effects on the function of the flux powder.

[0006] In another publication by Gigacher et al.: "Properties of High-Manganese Steels under Conditions Similar to Continuous Casting"; BHM 149 (2004), No. 3, pp. 112-117, it is stated in summary that the casting of the alloying concepts presented there for the production of TWIP steels is not advantageous for methods with flux powders.

[0007] The principal problem with the casting of steels with a high Al content (>1%) is the reaction of the Al from the steel with the oxide constituents of the flux powder. The reduction of the SiO_2 in the slag by the Al from the steel gives rise to Al_2O_3, which is absorbed by the slag and causes the basicity of the slag (the CaO/SiO_2 ratio) to increase. This leads to very sharp changes in viscosity and in the lubrication conditions in the mold.

[0008] Due to these difficulties, various approaches for the production of TWIP steels have been taken:

[0009] WO 02/101109 A1 discloses a method in which a significant reduction of the offset yield stress and thus an improvement of the formability by hot rolling and cold rolling are achieved by increasing the possible carbon content (C≦1%) and by adding additional elements, here especially B as well as Ni, Cu, N, Nb, Ti, V, and P. To produce this steel, a feedstock (slab, thin slab, or strip) is heated and hot rolled and coiled within specific temperature limits.

[0010] EP 1 341 937 B1 describes a method in which a steel containing 12-30% Mn is cast in a twin-roll casting machine into a near-net shape thin strip with a thickness of less than 1 mm to 6 mm. The near-net shape strip emerging vertically from the casting gap is cooled by coolants applied to its surface and is then rolled to the final thickness in a single hot rolling pass. The total time interval between the exit from the casting gap and the entry into the rolling stand is about 8 seconds.

[0011] EP 1 067 203 B1 discloses a method for producing strip made of an Fe—C—Mn alloy in which a thin steel strip with a thickness of 1.5-10 mm and a composition of 6-30% Mn, 0.001 to 1.6% C, ≦2.5 Si, ≦6% Al, ≦10% Cr and other elements is first cast on a twin-roll casting machine and then hot rolled in one or more stages with 10-60% reduction.

[0012] Based on this prior art, the objective of the invention is to specify a method and an installation which can be realized as simply as possible and with which high-manganese steels with a given chemical composition can be produced by continuous casting.

[0013] The objective with respect to the method is achieved by the characterizing features of Claim **1**, which involve the use of successive process steps, in which a light gauge steel with the given chemical composition of 15-27% Mn, 1-6% Al, 1-6% Si, ≦0.8% C with the remainder consisting of Fe and accompanying impurity elements

[0014] is cast on a thin-slab casting machine (d≦120 mm) with the use of suitable flux powders, which very quickly reach equilibrium and then undergo no further change in their lubrication behavior, and is then cut into slabs,

[0015] immediately after the solidification and cutting of a slab, temperature equalization is brought about in a continuous-type intermediate furnace, and then

[0016] the slab is immediately hot rolled without intermediate cooling.

[0017] An installation for carrying out the method is characterized by the features of Claim **7**.

[0018] In the production of thin slabs, for example, on CSP casting machines (CSP=Compact Strip Production), the strand is withdrawn vertically, bent horizontally after solidification, and then cut into slabs. Therefore, no problems can arise with internal cracks. The production of high-strength austenitic steels without installation overloading is possible and in the meantime has become the state of the art.

[0019] Microsegregations that are still present in the strand after solidification are largely removed again by diffusion during passage through the intermediate furnace, for example, through a roller hearth furnace, before the subsequent rolling deformation. In the process, the macrosegregations in the slab center are sufficiently equalized during the intense deformation in the hot rolling mill, much like high-grade austenitic steels.

[0020] In accordance with the invention, the use of the roller hearth furnace of a CSP installation advantageously avoids any relatively great depletion of the alloying elements and oxidation of the grain boundaries due to the short passage time. Depletion of the alloying elements and oxidation of the grain boundaries can cause problems, for example, during the relatively long heating times in the pusher furnace of a conventional hot-rolled wide strip mill in accordance with the prior art.

[0021] In accordance with the invention, to be able to use the technology of casting TWIP light gauge steels with high Mn and Al contents on a thin-slab casting machine, it is necessary to use a suitable flux powder. In accordance with the invention, a suitable flux powder is one which has the property of achieving equilibrium very quickly and then undergoing no further change in its lubrication behavior.

[0022] In order, for example, to reduce the reaction rate of the SiO_2 reduction by the Al in the steel, the flux powder used in accordance with the invention has a high content of Al_2O_3 of >10%. Alternatively or additionally, to have more SiO_2 available in the equilibrium state, the SiO_2 content of the flux powder is increased sufficiently to obtain a basicity (CaO/SiO_2 ratio) of 0.5-0.7.

[0023] Since MnO_2 is more readily reduced than SiO_2 by the Al in the steel, and thus the SiO_2 is protected from this reduction (protected from loss), an additional measure that can be taken in accordance with the invention is the addition of MnO_2 to the flux powder.

[0024] In accordance with the invention, it is also possible to add TiO_2 to the flux powder as a partial replacement of the SiO_2, since TiO_2 also has a vitrifying effect but is not attacked (reduced) by the Al in the steel.

[0025] Finally, it is also possible to lower the viscosity of the flux powder in the mold. This increases the consumption of flux powder, and more of the Al_2O_3 that is formed is removed, so that an equilibrium with lower Al_2O_3 concentrations is established. This reduction in viscosity is achieved by the addition of B_2O_3 (borate), Na_2O, and/or LiO_2 to the flux powder.

[0026] The process diagram of an installation of the invention for producing hot-rolled strip is shown in the schematic drawing and is explained in detail below.

[0027] The installation is basically a well-known CSP installation, in which, in accordance with the invention, the distances between the individual installation units were changed in such a way that the method of the invention can be carried out with the requirements that temperature equalization is brought about in a continuous-type intermediate furnace immediately after the solidification and that the slab is then immediately hot rolled without intermediate cooling.

[0028] Accordingly, the installation illustrated in the drawing consists of a thin-slab casting machine **1** and a downstream intermediate furnace **4**, into which the slab **3** is fed after it has solidified and has been cut from the endless strand **2**. The intermediate furnace **4** is followed by a rolling mill **5**, in which the slab **3**, after it has been subjected to temperature equalization in the intermediate furnace **4**, is immediately (i.e., without intermediate cooling) rolled out into hot-rolled strip **6**.

1. Method for producing hot-rolled strip (**6**) from a highly cold-workable, high-strength, austenitic light gauge steel with increased contents of manganese (Mn), aluminum (Al), and silicon (Si) with TWIP properties (Twinning-Induced Plasticity), wherein the light gauge steel is first cast into an endless strand (**2**) in a continuous casting installation (**1**), cut into slabs (**3**), and then rolled to the final thickness, wherein successive process steps are used, in which a light gauge steel with the given chemical composition of 15-27% Mn, 1-6% Al, 1-6% Si, ≦0.8% C, with the remainder consisting of Fe and impurities

is cast on a thin-slab casting machine (**1**) (d≦120 mm) with the use of flux powders and cut into slabs (**3**), such that suitable mineral substances are added to the flux powders to reduce the reaction rate of the SiO_2 reduction by the Al in the steel and/or to reduce the amount of Al_2O_3 that is formed by lowering the viscosity in the mold,

immediately after the solidification of the endless strand (**2**) and cutting of a slab (**3**), temperature equalization is brought about in a continuous-type intermediate furnace (**4**), and then

the slab (**3**) is immediately hot rolled without intermediate cooling.

2. Method in accordance with claim **1**, wherein the flux powder has an increased Al_2O_3 content of >10%.

3. Method in accordance with claim **1**, wherein the flux powder has an increased SiO_2 content with a basicity (CaO/SiO_2 ratio) of 0.5-0.7.

4. Method in accordance with claim **1**, wherein the flux powder contains MnO_2 and/or TiO_2.

5. Method in accordance with claim **1**, wherein, to lower the viscosity of the flux powder in the mold, the flux powder contains B_2O_3 (borate), Na_2O, and/or LiO_2.

6. Method in accordance with claim **1**, wherein the intermediate furnace (**4**) is a roller hearth furnace.

7. Installation for producing hot-rolled strip from a highly cold-workable, high-strength, austenitic light gauge steel with increased contents of manganese (Mn), aluminum (Al), and silicon (Si) with TWIP properties (Twinning-Induced Plasticity) for carrying out the method in accordance with claim **1**, which consists of a CSP installation (Compact Strip Production) with the successively arranged installation units thin-slab casting machine (**1**), intermediate furnace (**4**), and hot rolling mill (**5**), wherein the distances between the individual installation units are changed in such a way that immediately after the solidification of the endless strand (**2**), temperature equalization of a cut slab (**3**) is brought about in a continuous-type intermediate furnace (**4**), and then the slab (**3**) is immediately hot rolled without intermediate cooling.

* * * * *