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(54) METHOD FOR PRODUCING STEEL STRIP OF CARBON STEEL

VERFAHREN ZUR ERZEUGUNG VON STAHLSTREIFEN AUS KOHLENSTOFFSTAHL

PROCÉDÉ POUR PRODUIRE UNE BANDE D'ACIER EN ACIER AU CARBONE

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Description

[0001] The invention relates to a method for producing steel strip of carbon steel using a thin slab caster such as a direct sheet plant (DSP) or direct sheet caster (DSC), in which the steel is continuously cast and in the same installation semi-continuously rolled, or a conventional slab caster with a hot connect to a hot rolling installation.

[0002] It is known that it is difficult to produce peritectic steels having a carbon content in the order of 0.1 wgt%. The surface quality of the slabs deteriorates as a result of the volume changes which accompany the transformation from the ferritic phase to the austenitic phase; surface cracking or break-outs of the partially solidified shell occur, which cause damage to the installation and production delays. Moreover, on continuous casters with hot-connect, such as a DSP or CSP, rectifications of surface defects is not generally possible and surface defects on the cast strand lead to surface defects on the coil. As a result, steels having a carbon content above approximately 0.075 wgt% are not produced in this way. In contrast, slabs produced in conventional casters can be inspected and repaired before rolling, so it is possible to cast peritectic steels on conventional casters and roll these on a hot rolling installation.

[0003] Furthermore it is known that certain elements influence the carbon content in which steel is peritectic. This can be determined by a formula for the so-called carbon equivalent, in which the elements in the formula give a fictive carbon content. An overview of these elements determining the carbon equivalent is given in the article "Calculation of the Peritectic Range for Steel Alloys" by Kenneth E. Blazek et. al. in Iron & Steel Technology, 2008, Vol. 5, No. 7, pp. 80-85.

[0004] Document US6 855 218 B1 discloses a method for producing steel strip using a thin slab caster with a hot connect to a hot rolling installation. The steel composition preferably comprises (in wt%) 0.12-0.3 C, 1.2-3.5 Mn, 1.1.-2.2 Al.

[0005] It is the object of the invention to provide a method for producing steel strip of carbon steel using a thin slab caster such as a DSP or DSC for continuously casting the carbon steel or a conventional slab caster with a hot connect to a hot rolling installation.

[0006] It is a further object of the invention to provide a steel strip with a steel composition that can be used on a thin slab caster.

[0007] According to the invention one or more of these objects is reached by providing a method for producing steel strip of carbon steel using a thin slab caster such as a DSP or DSC for continuously casting the carbon steel or a conventional slab caster with a hot connect to a hot rolling installation, comprising the following steps:

providing a molten steel containing the following elements (in weight %):

0.06 - 0.17 C
max 3.0 Mn
0.11 - 2.0 Al
max 0.01 Ca
0.1 - 0.5 Si and optionally one or more of the following elements:

max 1.0 Cr
max 1.0 Mo
max 0.1 P
max 1.0 Cu
max 2.5 Ni
max 0.2 V
max 0.2 Ti
max 0.1 Nb
max 0.01 B

the remainder being Fe and unavoidable impurities;
providing the molten steel to the mould of a thin slab caster or conventional slab caster with hot connect;
casting the steel into a strand;
cutting the strand into slabs;
rolling the slabs into strips after the slabs have undergone a temperature equalizing or reheating step.

[0008] The carbon steel types known from the prior art that are suitable for casting using a thin slab caster or conventional caster with hot connect all have an Al content below 0.1 weight %. The inventors have found that aluminium is the most suitable element to increase the carbon equivalent of the steel, such that steels having a carbon content between 0.06 and 0.17 weight % can be used in a thin slab caster or conventional caster with hot connect outside the peritectic range. In many cases the addition of Al to a hitherto peritectic steel does not impair the performance of the product. In particular in advanced high strength steels the addition of aluminium improves the formability of the steel by the TRIP effect.

[0009] Manganese is added as austenite stabiliser and to give strength to the steel. It is unusual to add more than 3 weight % manganese in view of casting problems. The optional elements mentioned above are added when such is desired to provide a specific steel quality. These elements are usually added to change the mechanical properties and the purpose for which the steel type is used. Calcium is added to improve the castability and forms calciumaluminates with Al.

[0010] It is possible that the steel contains a more limited amount of carbon, for instance 0.07 - 0.15 weight % C, preferably 0.07 - 0.12 weight % C. In these more limited ranges for carbon the use of Al is especially needed.

[0011] It is also possible that the steel contains a more limited amount of manganese, for instance 0.1 - 3.0 weight % Mn, preferably 0.5 - 2.5 weight % Mn, and more preferably 1.0 - 2.0 weight % Mn. Such more limited amounts of manganese are generally used in casting advanced high strength steels.

[0012] Furthermore, the aluminium content of the steel can be more limited, for instance when the carbon content

is more limited or when other elements are added. Preferably, the steel contains 0.3 - 1.5 weight % Al, more preferably 0.3 - 1.0 weight % Al, still more preferably 0.5 - 0.8 weight % Al.

[0013] The steel contains 0.1 - 0.5 weight % Si. Usually the amount of silicon in steel is kept relatively low.

[0014] Chromium is often added to certain steel types for strengthening the steel. Due to its price, usually only limited amounts are added in carbon steels. According to a preferred composition the steel contains 0.1 - 1.0 weight % Cr, more preferably 0.3 - 0.8 weight % Cr.

[0015] According to a preferred method the molten steel has the composition of an advanced high strength steel, such as a dual phase steel.

[0016] For the at present usual strength levels between 600 and 1200 MPa, such dual phase steels have a composition containing the following elements (in weight %):

0.06 - 0.17 C
0.9 - 3.0 Mn
0.1 - 2.0 Al
0.01 - 1.0 Cr
0.01 - 0.5 Si
max 0.01 Ca
max 0.5 Mo
max 0.05 P
max 0.1 Cu
max 0.1 Ni
max 0.1 Nb
max 0.01 B
the remainder being Fe and unavoidable impurities.

[0017] The elements in the dual phase steels as shown above are even more limited to reach certain strength levels, such as DP600, DP 800, DP1000 or DP1200. Apart from the amount of aluminium, the amount of the elements are known for dual phase steels that are not produced on a DSP, CSP or conventional slab caster with a hot connect.

[0018] According to a second aspect of the invention there is provided a hot rolled steel strip of carbon steel produced with the method according to the first aspect of the invention.

[0019] According to a third aspect of the invention there is provided a cold rolled and annealed steel strip of carbon steel produced by cold rolling and annealing the hot rolled steel strip according to the second aspect of the invention.

[0020] The invention will be elucidated referring to the example described below.

[0021] A steel type according to the invention has been cast, having the following composition in weight %:

C	0.090
Mn	1.650
Al	0.650
Si	0.250
Cr	0.575

the remainder being iron and inevitable impurities.

[0022] This steel type has been cast in the direct sheet plant (DSP) using a standard moulding powder in the mould, with a casting speed of approximately 4.5 m/min. After temperature equalisation in the tunnel oven, the slabs have been rolled in the seven-stand rolling equipment of the DSP to an end thickness of 3 mm.

[0023] Visual inspection of the cast slabs showed no transverse cracks in the surface of the slabs. Dropping experiments of cold slabs showed that the slabs are not prone to cracking during handling.

[0024] As a comparison, a typical standard steel type cast on the DSP has the following composition in weight %:

C	0.045
Mn	0.220
Al	0.035
Si	inevitable impurity
Cr	inevitable impurity

the remainder being iron and inevitable impurities.

[0025] The comparison between the standard steel type and the steel type according to the invention shows that the steel type according to the invention has a higher content of all the elements in the steel. This is partly due to the fact that it is the intention to produce an advanced high strength steel, in this case a dual phase steel, after cold rolling of the hot rolled strip.

[0026] The carbon content of 0.090 weight % in the steel type according to the invention is such that without additional measures a peritectic steel would be formed during solidification of the steel in the mould of the DSP, which transformation from the δ-phase to the γ-phase in the iron-carbon diagram causes changes in the volume of the steel leading to the loss of contact between the cast steel and the mould. This results in an irregular cooling of the steel slabs, in turn leading to cracks.

[0027] The addition of a larger amount of aluminium has been found to result in the steel being peritectic at higher carbon contents than usual. At 0.090 weight % carbon the steel is not peritectic in the mould; as a result the slab is cooled in the same way as the standard type steel, and no cracks occur. Without the cracks, the steel type according to the invention can be processed in the DSP without risks of surface cracking and damage to the installation due to break-outs.

[0028] The steel produced in accordance with the invention can be a hot rolled steel strip or a cold rolled and annealed steel strip, which in the latter case can be hot dip galvanised or galvannealed.

[0029] It will be clear that other steel types than the steel type of the example can be used in the DSP or

another caster with a hot connect to a hot rolling installation without the risks for the rolls of the DSP or the caster. The scope of protection is not limited by the example, but determined by the claims.

Claims

1. Method for producing steel strip of carbon steel using a thin slab caster such as a DSP (direct sheet plant) or DSC (direct sheet caster) for continuously casting the carbon steel or a conventional slab caster with a hot connect to a hot rolling installation, comprising the following steps:

   providing a molten steel containing the following elements (in weight %):

   0.06 - 0.17 C
   max 3.0 Mn
   0.1 - 2.0 Al
   max 0.01 Ca
   0.1-0.5 Si

   and optionally one or more of the following elements:

   max 1.0 Cr
   max 1.0 Mo
   max 0.1 P
   max 1.0 Cu
   max 2.5 Ni
   max 0.2 V
   max 0.2 Ti
   max 0.1 Nb
   max 0.01 B

   the remainder being Fe and unavoidable impurities;
   providing the molten steel to the mould of a thin slab caster or conventional slab caster with hot connect;
   casting the steel into a strand;
   cutting the strand into slabs;
   rolling the slabs into strips after the slabs have undergone a temperature equalizing or reheating step.

2. Method according to claim 1, wherein the molten steel contains 0.07 - 0.15 weight % C, preferably 0.07 - 0.12 weight % C.

3. Method according to claim 1 or 2, wherein the molten steel contains 0.1 - 3.0 weight % Mn, preferably 0.5 - 2.5 weight % Mn, more preferably 1.0 - 2.0 weight% Mn..

4. Method according to any one of the preceding claims, wherein the molten steel contains 0.2 - 1.5 weight % Al, preferably 0.3 - 1.0 weight % Al, more preferably 0.5 - 0.8 weight % Al.

5. Method according to any one of the preceding claims, wherein the molten steel contains 0.2 - 0.5 weight % Si.

6. Method according to any one of the preceding claims, wherein the molten steel contains 0.1 - 1.0 weight % Cr, preferably 0.3 - 0.8 weight % Cr.

7. Method according to any one of the preceding claims, wherein the molten steel has the composition of a dual phase steel.

8. Method according to any one of the preceding claims, wherein the molten steel has the composition of a dual phase steel and contains the following elements (in weight %):

   0.06 - 0.17 C
   0.9 - 3.0 Mn
   0.1 - 2.0 Al
   0.01 - 1.0 Cr
   0.1 -0.5 Si
   max 0.01 Ca
   max 0.5 Mo
   max 0.05 P
   max 0.1 Cu
   max 0.1 Ni
   max 0.1 Nb
   max 0.01 B
   the remainder being Fe and unavoidable impurities.

Patentansprüche

1. Verfahren zur Herstellung von Stahlband aus Kohlenstoffstahl unter Verwendung eines Dünnbrammengießers wie einer DSP (Direct Sheet Plant: Direktplattenanlage) oder eines DSC (Direct Sheet Caster: Direktplattengießers) zum durchgehenden Gießen des Kohlenstoffstahls oder eines konventionellen Brammengießers mit einer Warmverbindung zu einer Warmwalzanlage, die folgenden Schritte umfassend:

   Bereitstellen eines geschmolzenen Stahls, der die folgenden Elemente enthält (in Gew.-%):

   0,06 - 0,17 C
   max. 3,0 Mn
   0,1 - 2,0 Al
   max. 0,01 Ca
   0,1 - 0,5 Si

und optional eines oder mehrere der folgenden Elemente:

max. 1,0 Cr
max. 1,0 Mo
max. 0,1 P
max. 1,0 Cu
max. 2,5 Ni
max. 0,2 V
max. 0,2 Ti
max. 0,1 Nb
max. 0,01 B

wobei der Rest Fe und unvermeidbare Unreinheiten sind;
Bereitstellen des geschmolzenen Stahls für die Form eines Dünnbrammengießers oder konventionellen Brammengießers mit Warmverbindung;
Gießen des Stahls zu einem Strang;
Schneiden des Strangs in Brammen;
Rollen der Brammen zu Streifen, nachdem die Brammen einem Temperaturausgleich- oder Wiedererwärmungsschritt unterzogen wurden.

2. Verfahren nach Anspruch 1, wobei der geschmolzene Stahl 0,07 - 0,15 Gew.-% C, bevorzugt 0,07 - 0,12 Gew.-% C enthält.

3. Verfahren nach Anspruch 1 oder 2, wobei der geschmolzene Stahl 0,1 - 3,0 Gew.-% Mn, bevorzugt 0,5 - 2,5 Gew.-% Mn, bevorzugter 1,0 - 2,0 Gew.-% Mn enthält.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei der geschmolzene Stahl 0,2 - 1,5 Gew.-% Al, bevorzugt 0,3 - 1,0 Gew.-% Al, bevorzugter 0,5 - 0,8 Gew.-% Al enthält.

5. Verfahren nach einem der vorhergehenden Ansprüche, wobei der geschmolzene Stahl 0,2 - 0,5 Gew.-% Si enthält.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei der geschmolzene Stahl 0,1 - 1,0 Gew.-% Cr, bevorzugt 0,3 - 0,8 Gew.-% Cr enthält.

7. Verfahren nach einem der vorhergehenden Ansprüche, wobei der geschmolzene Stahl die Zusammensetzung eines Dualphasenstahls hat.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei der geschmolzene Stahl die Zusammensetzung eines Dualphasenstahls hat und die folgenden Elemente enthält (in Gew.-%):

0,06 - 0,17 C
0,9 - 3,0 Mn
0,1 - 2,0 Al
0,01 - 1,0 Cr
0,1 - 0,5 Si
max. 0,01 Ca
max. 0,5 Mo
max. 0,05 P
max. 0,1 Cu
max. 0,1 Ni
max. 0,1 Nb
max. 0,01 B

wobei der Rest Fe und unvermeidbare Unreinheiten sind.

Revendications

1. Procédé de production d'une bande d'acier au carbone au moyen d'une machine à couler des brames minces telle qu'un DSP (direct sheet plant : installation permettant la production directe de tôles) ou un DSC (direct sheet caster : machine de coulée permettant la production directe de tôles) pour couler en continu l'acier au carbone ou d'une machine à couler des brames conventionnelles avec raccordement chaud à une installation de laminage à chaud, comprenant les étapes suivantes :

approvisionnement d'un acier fondu contenant les éléments suivants (en % en poids) :

0,06 à 0,17 de C
3,0 max de Mn
0,1 à 2,0 d'Al
0,01 max de Ca
0,1 à 0,5 de Si

et éventuellement un ou plusieurs des éléments suivants :

1,0 max de Cr
1,0 max de Mo
0,1 max de P
1,0 max de Cu
2,5 max de Ni
0,2 max de V
0,2 max de Ti
0,1 max de Nb
0,01 max de B

le reste étant du Fe et des impuretés inévitables ;
approvisionnement de l'acier fondu dans le moule d'une machine à couler des brames minces ou d'une machine à couler des brames conventionnelles avec raccordement chaud ;
coulée de l'acier en toron ;
découpage du toron en brames ;

laminage des brames en bandes après que les brames aient subi une étape d'égalisation de température ou de réchauffage.

2. Procédé selon la revendication 1, ledit acier fondu contenant 0,07 à 0,15 % en poids de C, de préférence 0,07 à 0,12 % en poids de C.

3. Procédé selon la revendication 1 ou 2, ledit acier fondu contenant 0,1 à 3,0 % en poids de Mn, de préférence 0,5 à 2,5 % en poids de Mn, plus préférablement 1,0 à 2,0 % en poids de Mn.

4. Procédé selon l'une quelconque des revendications précédentes, ledit acier fondu contenant 0,2 à 1,5 % en poids d'Al, de préférence 0,3 à 1,0 % en poids d'Al, plus préférablement de 0,5 à 0,8 % en poids d'Al.

5. Procédé selon l'une quelconque des revendications précédentes, ledit acier fondu contenant 0,2 à 0,5 % en poids de Si.

6. Procédé selon l'une quelconque des revendications précédentes, ledit acier fondu contenant 0,1 à 1,0 % en poids de Cr, de préférence 0,3 à 0,8 % en poids de Cr.

7. Procédé selon l'une quelconque des revendications précédentes, ledit acier fondu ayant la composition d'un acier à deux phases.

8. Procédé selon l'une quelconque des revendications précédentes, ledit acier fondu ayant la composition d'un acier à deux phases et contenant les éléments suivants (en % en poids) :

0,06 à 0,17 de C
0,9 à 3,0 de Mn
0,1 à 2,0 d'Al
0,01 à 1,0 de Cr
0,1 à 0,5 de Si
0,01 max de Ca
0,5 max de Mo
0,05 max de P
0,1 max de Cu
0,1 max de Ni
0,1 max de Nb
0,01 max de B

le reste étant du Fe et des impuretés inévitables.

REFERENCES CITED IN THE DESCRIPTION

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