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(54) **METHOD FOR PRODUCING A HOT STRIP FROM A STEEL WHICH HAS A HIGH MANGANESE CONTENT**

(75) Inventors: **Bernhard Engl**, Dortmund (DE); **Dieter Senk**, Dinslaken (DE); **Johann Wilhelm Schmitz**, Baesweiler (DE); **Andreas Offergeld**, Ratingen (DE)

Correspondence Address:
PROSKAUER ROSE LLP
PATENT DEPARTMENT
1585 BROADWAY
NEW YORK, NY 10036-8299 (US)

(73) Assignee: **ThyssenKrupp Stahl AG**, Duisburg (DE)

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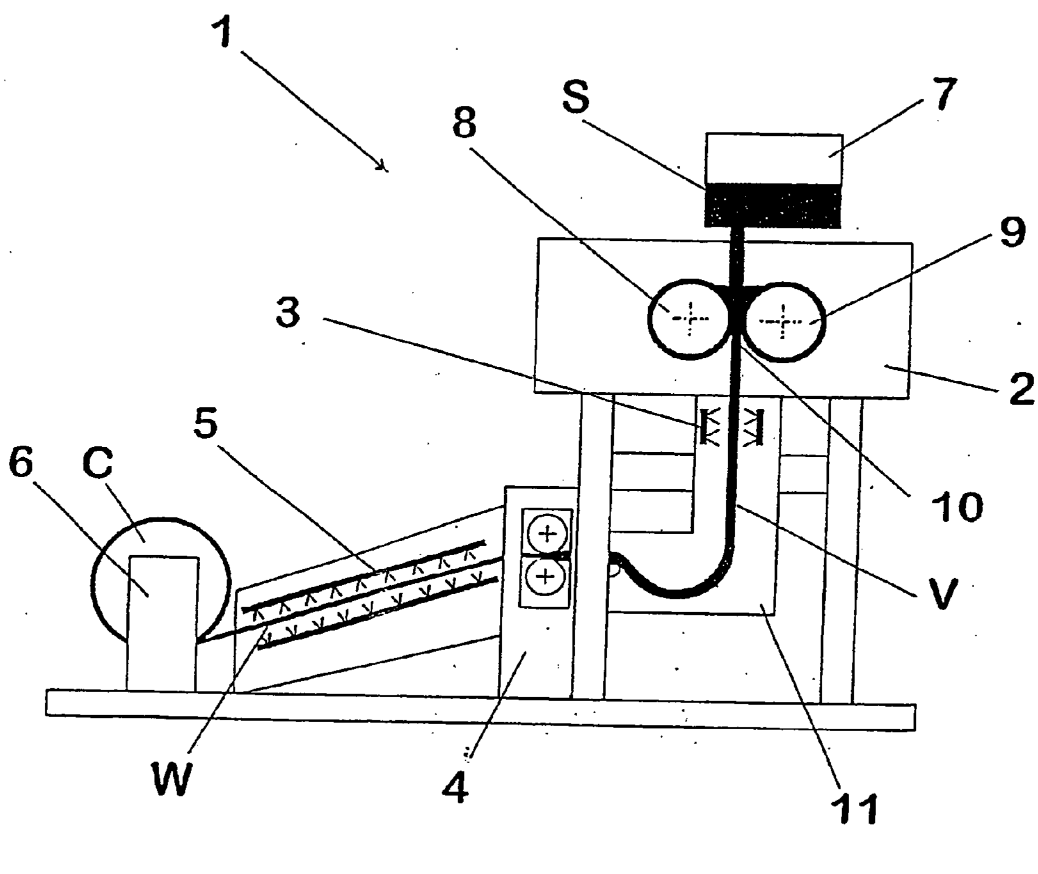
(57) **ABSTRACT**

A steel strip can be produced which in spite of its high manganese content has good deformation behaviour in that, according to the invention, from a steel which comprises more than 12 to 30 weight % of manganese, a roughed strip (V) is cast close to the final dimensions in a double-roller casting machine (**2**), said roughed strip comprising a thickness of up to 6 mm. Following casting, this roughed strip is further processed to form a continuous hot strip by preferably being rolled in a single hot roll pass.



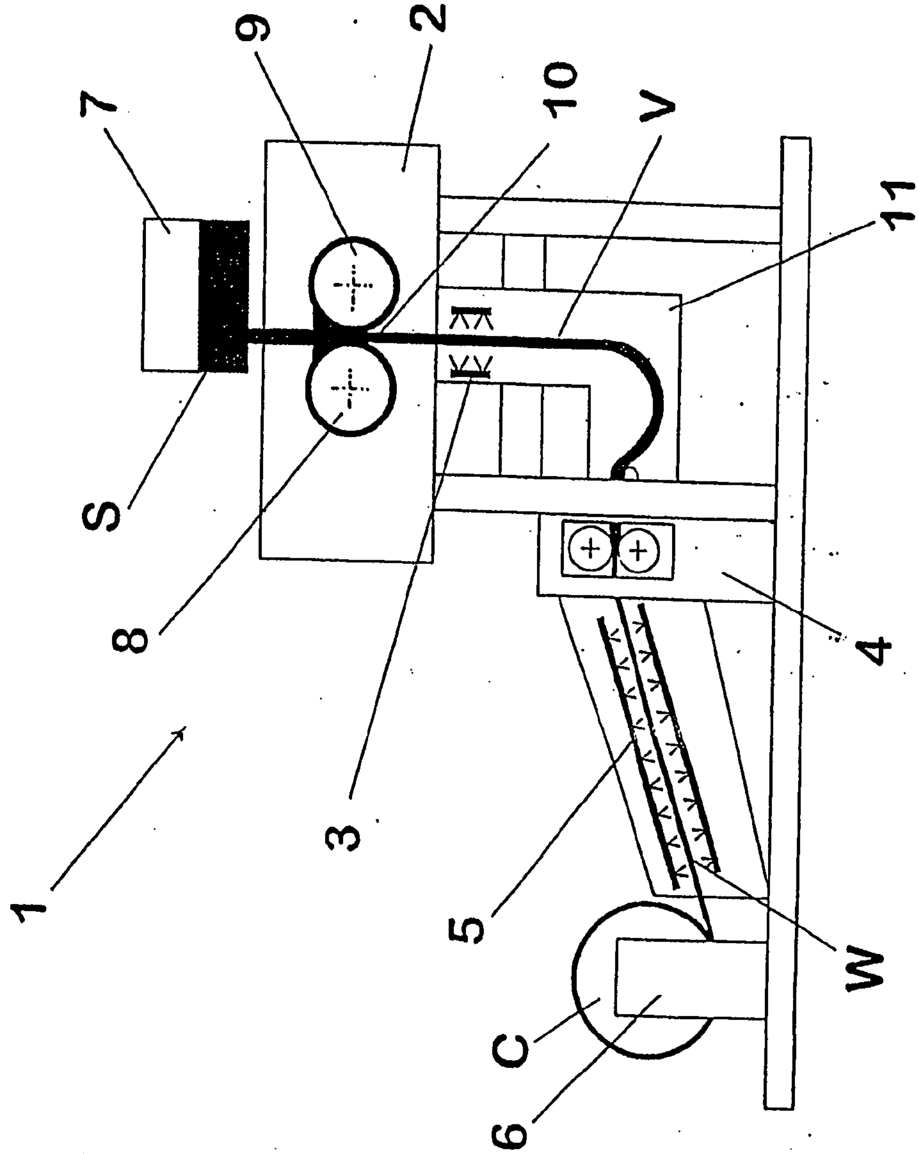


Figure 1

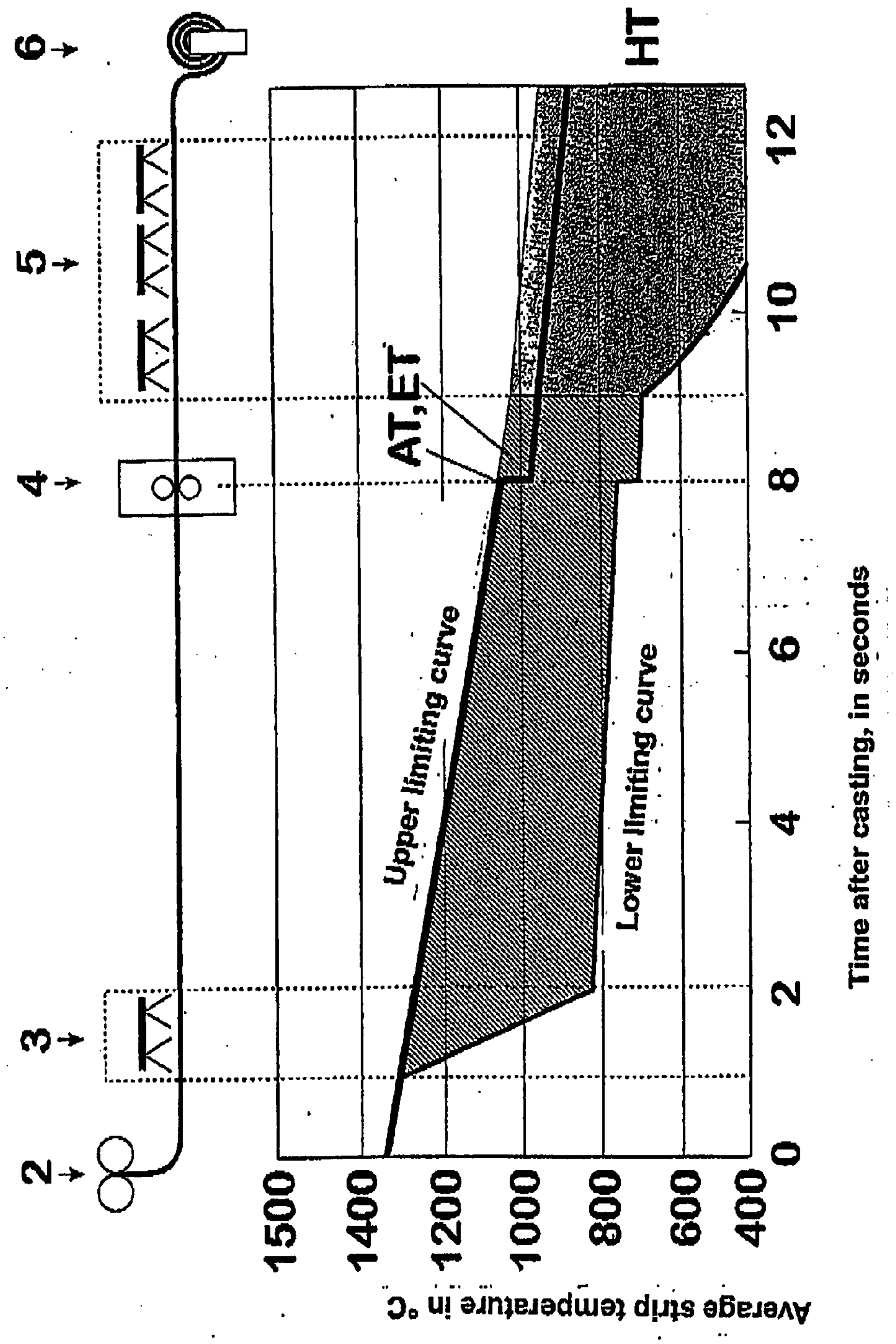

2
3
4
5
6
HT
AT,ET
Upper limiting curve
Lower limiting curve
1500
1400
1200
1000
800
600
400
Average strip temperature in °C
0
2
4
6
8
10
12
Time after casting, in seconds

Figure 2

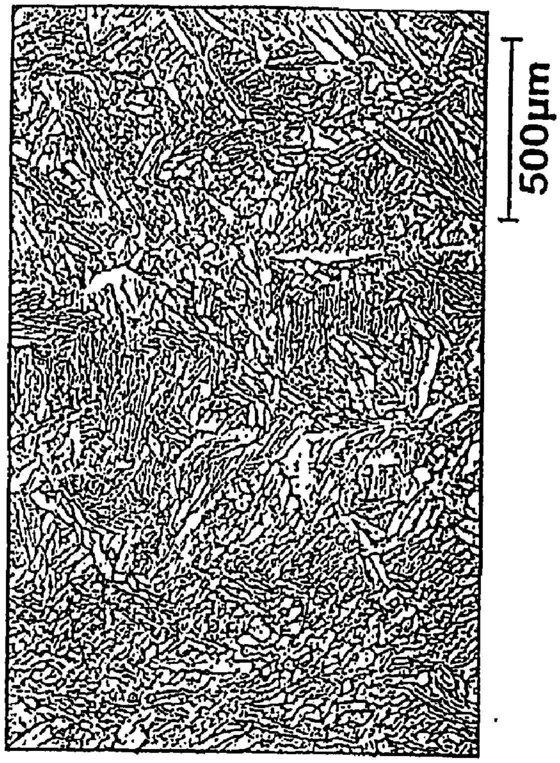


Figure 3b

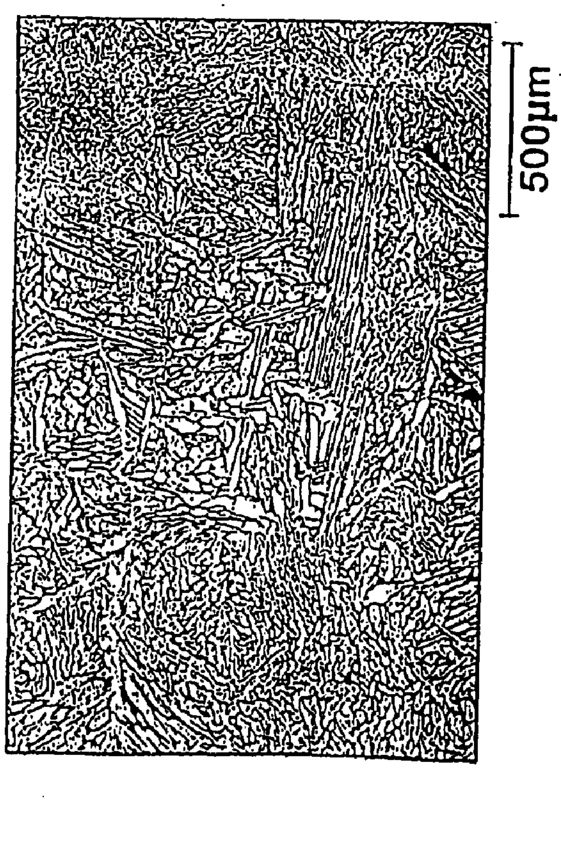


Figure 3a

METHOD FOR PRODUCING A HOT STRIP FROM A STEEL WHICH HAS A HIGH MANGANESE CONTENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application of U.S. Ser. No. 10/433,729, filed on Oct. 7, 2003. U.S. Ser. No. 10/433,729 is a national stage of PCT/EP01/14306, filed on Dec. 6, 2001. PCT/EP01/14306 originates from German application DE 100 69 948.1, filed on Dec. 6, 2000. The disclosures of each application listed above are incorporated by reference in their entireties.

DESCRIPTION

[0002] The invention relates to a method for producing a hot strip from a steel which has a high manganese content of more than 12 to 30 weight %. Steels of this type are characterised by particularly high strength.

[0003] There is a problem when producing and processing steels with such high manganese contents in that their solidification behaviour differs from that of steels which are commonly used for deep-drawing applications, for example IF or Low-carbon steels. It has thus been shown that steels of the type in question with a high manganese content, which steels have been cast in conventional continuous slab casting, have poor deformation behaviour.

[0004] According to a method known from DE 199 00 199 A1, steels which apart from other alloying elements comprise 7% to 27% Mn can be produced by thin-strip casting to form a strip which is close to the final dimensions, and can be processed into hot strip. The material obtained in this way is particularly suitable for application in the area of motor car body construction.

[0005] It is the object of the invention to provide a method which makes it possible to produce steel strip of good deformation behaviour, in spite of a high manganese content.

[0006] This object is met by a method for producing a hot strip with TWIP and TRIP characteristics, from a steel which comprises more than 12 to 30 weight % of manganese, in which a melt is cast in a double-roller casting machine to form a roughed strip close to the final dimensions, said roughed strip comprising a thickness of up to 6 mm, which roughed strip, following casting, is further continuously processed to form hot strip by being rolled in a single hot roll pass to the final thickness of the hot strip.

[0007] According to the invention, highly manganiferous steel is cast to form a raw material whose dimensions approximate the final dimensions of the hot strip. In this way during the casting process already, the material produced is so thin that essentially uniform solidification across its entire cross section is ensured. Surprisingly, it has been shown that the microstructure of the raw material which was cast to be so close to final dimensions is essentially of finer grain and more uniform than is the case in steel strip with a comparatively high manganese content, which was produced in the conventional way. The hot strip produced from the raw material has TRIP ("Transformation Induced Plasticity") and TWIP ("Twinning Induced Plasticity") characteristics and consequently is of good deformability which in combination with its high strength make it eminently suitable for use in motor car body construction.

[0008] According to the invention, the material produced should be as thin as possible. The thinner the cast raw material, the finer the solidification microstructure, and the less scope there is for flaws due to solidification impeding the further processing to form hot strip. At the same time, in a thin cast raw material, the solidification process can easily be controlled in a targeted way. Thus, a controlled process can take account of the fact that, in particular in the case of steels under discussion in this document, the solidification rate has a direct influence on the extent and distribution of micro segregation. This in turn has an influence on grain growth and on the state of the precipitation such as of MnS, AlN and Ti (C, N) which occurs during solidification. As a result of targeted control of the microstructure parameters of the cast raw material, it is thus possible to select the basic settings which have a decisive influence on the ability for further processing and on the usage characteristics of the end product.

[0009] According to the invention, the steel is cast in a double-roller casting machine. This type of casting machine, which is known per se, makes it possible to produce particularly thin raw material which closely approximates the final dimension of the hot strip, with the solidification behaviour, in particular the solidification rate and uniformity of solidification, of such raw material resulting in an optimum cast structure and, associated with it, in optimum deformability.

[0010] Surprisingly it has been shown that particularly good work-results can be achieved in that from the roughed strip, a hot strip is rolled to its final thickness in only a single pass. The immediate continuous sequence of the casting process and hot rolling in one pass makes it possible to take the heat of the casting process along into the rolling process. Consequently, the step of reheating before hot rolling, a step which is always required in conventional slab casting, can be avoided. "Taking along" the casting heat also prevents excessive crystal growth, thus additionally supporting the formation of a fine microstructure in the raw material.

[0011] Due to the particular influence of the solidification process on the characteristics of the final product it is advantageous if further processing of the raw material to form hot strip comprises controlled cooling, which takes place immediately after casting. This makes it possible to cool in a targeted way the raw material issuing from the casting mould so as to obtain a microstructure which is optimised for further processing. As a rule, cooling will take place at a rate which is accelerated when compared to cooling by exposure to ambient air.

[0012] Experiments have shown that, depending on the composition and the desired characteristics of the end product, the average initial rolling temperature at which the raw material enters the roll stand can range between 1100° C. and 750° C.

[0013] If the raw material is hot rolled, the characteristics of the hot-rolled strip can furthermore be influenced in a targeted way in that, following hot rolling, the rolled hot strip is cooled in a controlled way.

[0014] In principle it is imaginable to further process the hot strip obtained according to the invention "inline", for example to form a cold strip. However, with a view to possibly following process steps, or to characteristics of the hot strip to be set, it will in many cases be expedient for the strip to be coiled as part of further processing.

[0015] As a result of further processing of the raw material to form hot strip, at least in sections taking place in a protective gas atmosphere, oxidation of the strip surface, and associated with it excessive scale formation, can be avoided. In this context it is particularly favourable if the raw material is kept in the protective gas atmosphere at least until said raw material enters the roll stand.

[0016] Apart from further alloying elements, steels which are used according to the invention can comprise up to 3.5 weight %, in particular up to 3 weight %, silicon. Moreover, they can comprise up to 3.5 weight %, in particular up to 3 weight %, aluminium. In steel of the type processed according to the invention, iron and aluminium or iron and silicon form intermetallic phases which occur below the hot forming temperature and which are stable to room temperature.

[0017] Below, the invention is explained in more detail by means of one embodiment. The following are shown:

[0018] FIG. **1** A lateral diagrammatic view of the design of a device for producing hot strip;

[0019] FIG. **2** The temperature course during the processing time of the roughed strip and the hot strip in a device according to FIG. **1**;

[0020] FIG. **3***a* An enlarged section of the edge region of the hot strip produced in the device according to FIG. **1**; and

[0021] FIG. **3***b* An enlarged section of the centre region of the hot strip produced in the device according to FIG. **1**.

[0022] FIG. **1** diagrammatically shows the design of a device **1** for producing a hot strip W, said device comprising a casting device **2**, a first cooling section **3**, a roll stand **4**, a second cooling section **5**, and a coiling device **6**.

[0023] In a double-roller casting machine **2** designed according to the known principle, a melt S contained in a tundish **7**, with the melt composition being explained in detail below, is poured into the casting gap **10** formed between two casting rollers **8**, **9**, to form roughed strip V. The cast roughed strip V leaves the casting gap **10** in a continuous conveying process at a thickness which can be varied between less than 1 mm and 6 mm.

[0024] On its way to the roll stand **4**, the roughed strip V is cooled in a controlled way by means of a cooling medium applied to the surfaces of said roughed strip V in the first cooling section **3** which is arranged below the exit of the casting gap **10** and closely adjacent to it.

[0025] The conveyor section along which the thin strip V passes between the exit of the casting gap **10** and the roll stand **4** is surrounded by a dog house **11** in which a protective gas atmosphere is maintained. In this way, contact between the surface of the strip and the oxygen of the ambient air is avoided.

[0026] The thin strip V enters the roll stand **4** at an initial rolling temperature AT, and in said roll stand is rolled to final thickness in one pass.

[0027] Immediately thereafter, the hot strip W which leaves the roll stand **4** at a final rolling temperature ET passes through the second cooling section **5**. In the cooling section **5**, the hot strip W is again brought in a controlled way to the coiling temperature HT by means of a suitable cooling medium, before being coiled in the coiling device **6**, at said coiling temperature HT, to form a coil C.

[0028] FIG. **2** shows the initial rolling temperature AT, the final rolling temperature ET and the coiling temperature HT during the processing time after casting in the strip widths which, depending on the composition and the desired characteristics of the hot strip to be produced, can be set in a device designed according to FIG. **1**. By means of suitable temperature control management along a specified limiting curve, with subsequent isothermal holding, rolling and quenching, the fine grained microstructure of the hot strip can be frozen after the hot strip exits from the roll stand, so that the good usage characteristics of the hot strip remain after hot rolling. This effect can be achieved in particular when the temperature course of the roughed strip and hot strip approximates the lower limiting curve shown in the diagram (FIG. **2**).

[0029] Apart from the usual unavoidable impurities, the melt S which was poured in the embodiment shown comprised an Mn content of 20 weight %, a C content of 0.003 weight %, a sulphur content of 0.007 weight %, an Si content of 3.0 weight %, an Al content of 3.0 weight %, with the remainder being iron.

[0030] FIG. **3***a* shows an enlarged section of the edge region, while FIG. **3***b* shows an equally enlarged section of the centre region of a steel made from a hot strip produced in a device shown in FIG. **1**. It is evident that the strip comprises a dendritic microstructure comprising austenite and a second phase which is probably a carboniferous phase. The microstructure becomes significantly finer towards the core of the strip.

Reference Characters

[0031] **1** Device

[0032] **2** Double-roller casting machine

[0033] **3** First cooling section

[0034] **4** Roll stand

[0035] **5** Second cooling section

[0036] **6** Coiling device

[0037] **7** Tundish

[0038] **8**,**9** Casting rollers

[0039] **10** Casting gap

[0040] **11** Dog house

[0041] AT Initial rolling temperature

[0042] C Coil

[0043] ET Final rolling temperature

[0044] S Melt

[0045] V Thin strip

[0046] W Hot strip

What is claimed is:

1. A method for producing a steel hot strip with TWIP and TRIP characteristics from a steel which comprises more than 12 weight % and up to 30 weight % of manganese, comprising

casting a melt in a double-roller casting machine so as to form a roughed strip at close to the final dimensions of said hot strip, said roughed strip having a thickness of up to 6 mm,

immediately after said casting step and without reheating said roughed strip, continuously processing said roughed strip by being hot rolled in a roll stand in a single hot roll pass to the final thickness of the hot strip, said hot strip having a fine-grained dendritic microstructure after the single hot roll pass.

2. The method of claim 1 wherein the thickness of the roughed strip is up to 4 mm.

3. The method of claim 1 wherein the thickness of the roughed strip is up to 2.5 mm.

4. The method of claim 1 further comprising cooling said roughed strip under controlled conditions immediately after casting.

5. The method of claim 4 wherein said cooling is conducted at a rate which is greater than the rate of cooling by exposure to ambient air.

6. The method of claim 1 wherein the average initial rolling temperature at which the roughed strip enters the roll stand for hot rolling is in the range between 750° C. and 1,100° C.

7. The method of claim 1 further comprising cooling the hot strip under controlled conditions after hot rolling to freeze in the fine-grained dendritic microstructure.

8. The method of claim 1 further comprising coiling the hot strip.

9. The method of claim 1 wherein processing of the roughed strip to form said hot strip takes place, at least in sections, in a protective gas atmosphere.

10. The method of claim 9 wherein the roughed strip is kept under said protective gas atmosphere at least until it enters said roll stand.

11. The method of claim 1 wherein the steel comprises up to 3.5 weight % of silicon.

12. The method of claim 1 wherein said steel comprises up to 3 weight % of silicon.

13. The method of claim 1 wherein said steel comprises up to 3.5 weight % aluminum.

14. The method of claim 1 wherein the steel comprises up to 3 weight % of aluminum.

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