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(54) METHOD FOR MANUFACTURING FLAT STEEL PRODUCTS FROM BORON MICROALLOYED MULTI-PHASE STEEL

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(57) **ABSTRACT**

A method, which allows high-tensile flat steel products to be manufactured with less effort includes a steel that forms a multi-phase microstructure and contains (in wt. %) 0.08-0.12% C, 1.70-2.00% Mn, up to 0.030% P, up to 0.004% S, up to 0.20% Si, 0.01-0.06% Al, up to 0.0060% N, 0.20-0.50% Cr, 0.010-0.050% Ti, 0.0010-0.0045% B, remainder iron and unavoidable impurities, being cast into a cast strip having a thickness of 1-4 mm. The cast strip is hot-rolled in-line into a hot-rolled strip having a thickness of 0.5-3.2 mm in a continuous process at a final hot-rolling temperature ranging from 800 to 1100° .C, the deformation degree being greater than 20%. The hot-rolled strip is coiled at a coiling temperature ranging from 250 to 570° C., so as to obtain a hot-rolled strip, which has a minimum tensile strength R_m of 800 MPa at a minimum breaking elongation A_{80} of 5%.

METHOD FOR MANUFACTURING FLAT STEEL PRODUCTS FROM BORON MICROALLOYED MULTI-PHASE STEEL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a National Phase Application of International Application No. PCT/EP2007/061390, filed on Oct. 24, 2007, which claims the benefit of and priority to European patent application no. EP 06 123 139.5, filed on Oct. 30, 2006. The disclosures of the above applications are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[0002] The invention relates to a method for manufacturing flat steel products, such as strips or sheet metal blanks, from high-tensile, boron microalloyed steels. Such steels belong to the group of multi-phase steels. These are usually steels, the properties of which are determined by type, quantity and alignment of the phases of the microstructure. Therefore at least two phases exist in the microstructure (ferrite, martensite, bainite for example). As a result, they have a superior strength/formability combination compared to conventional steels.

BACKGROUND

[0003] Because of these special features, multi-phase steels are of major interest for automotive construction, since due to their high strength on the one hand they allow the use of smaller material thicknesses and consequently at the same time a reduction in the vehicle weight and on the other hand improve the safety of the vehicle body in the event of a collision (crash behavior). Thus, multi-phase steels with at least equal strength of the overall body permit a reduction in the sheet metal thickness of a component made from such multi-phase steels compared to a body made from conventional steels.

[0004] Usually, multi-phase steels are melted in a converter steel mill and cast on a continuous casting machine into slabs or thin slabs, which are then hot-rolled into hot-rolled strip and coiled. In this case the mechanical properties of the hot-rolled strip can be varied by selectively controlled cooling of the hot-rolled strip after hot-rolling with the aim of adjusting certain microstructural fractions. The hot-rolled strip can also be cold-rolled into cold-rolled strip in order to also obtain thinner sheet metal thicknesses (EP 0 910 675 B1, EP 0966547 B1, EP 1 169486 B1, EP 1 319725 B1, EP 1 398390 A1).

[0005] This manufacturing route creates problems particularly with respect to casting compositions solidifying peritectically. In the case of these steel grades there is a risk of longitudinal cracks arising during continuous casting. The emergence of such longitudinal cracks can lower the quality of the hot-rolled strip produced from cast slabs or thin slabs so severely that they become unusable. In order to prevent this risk, extensive measures are necessary, such as increased flame treatment, which can go as far as making the conversion of such steel grades uneconomic. When casting steel with high Al content, unwanted effects also come about due to interaction with the powdered fluxes, as the result of which the quality of a flat product made from this steel is also negatively affected.

[0006] A problem with manufacturing flat products from high-tensile multi-phase steels with a tensile strength of more than 800 MPa is that high rolling forces must be applied when rolling such steels. This requirement has the consequence that normally with the production machines at present generally available, high-tensile hot-rolled strip made from steel of the type under discussion can often only be manufactured in a width and thickness, which no longer fully meet the requirements demanded today by the automotive industry. In particular, strip of narrow thickness with sufficient width cannot be produced very well in conventional installations. Also, with conventional methods it is shown in practice that it is difficult to manufacture cold-rolled strip with a strength of more than 800 MPa from multi-phase steel.

[0007] An alternative way to produce steel strip from a multi-phase steel has been proposed in the European Patent EP 1 072 689 B1 (DE 600 09 611 T2). In accordance with this known method firstly a steel melt, which (in wt. %) contains 0.05 and 0.25% C, in total 0.5-3% Mn, Cu and Ni, in total 0.1-4% Si and Al, in total up to 0.1% P, Sn, As and Sb, in total less than 0.3% Ti, Nb, V, Zr and REM (i.e., rare earth metals) as well as in each case less than 1% Cr, Mo and V, remainder iron and unavoidable impurities, is cast into cast strip having a thickness of 0.5-10 mm, in particular 1-5 mm. The cast strip is subsequently hot-rolled in-line into a hot-rolled strip in one or more passes, the deformation degree ranging between 25% and 70%. The final hot-rolling temperature in this case is above the Ar_3 temperature. At the end of hot-rolling, the obtained hot-rolled strip is then cooled down in two steps. In the first step of this cooling a cooling rate of 5-100° C. per second is maintained until a temperature ranging between 400-550° C. is reached. The hot-rolled strip is then held at this temperature for a dwell time, which is needed in order to allow bainitic transformation of the steel with a residual austenite content greater than 5%. The formation of pearlite in this case is to be avoided. After a dwell time sufficient to obtain the required microstructure, the transformation process is interrupted by the beginning of the second cooling step, wherein the hot-rolled strip is brought to a temperature below 400° C., in order then to wind it into a coil at a coiling temperature below 350° C.

[0008] With the method described in EP 1 072 689 B1 it should be possible to produce hot-rolled strip with bainitic microstructural fractions in a simple way from a multi-phase steel, which has TRIP characteristics ("TRIP"="Transformation Induced Plasticity"). Such steel has relatively high strength with good formability. However, the strength is not sufficient for many applications, particularly in the field of automotive construction.

SUMMARY OF THE INVENTION

[0009] In general, an aspect of the invention is to provide a method, which allows high-tensile flat steel products to be manufactured with less effort in a wide range of geometrical dimensions.

[0010] In one embodiment, the aspect indicated above has been achieved by a method for manufacturing flat steel products, wherein according to the invention a steel that forms a multi-phase microstructure, which (in wt. %) contains 0.08-0.12% C, 1.70-2.00% Mn, up to 0.030% P, up to 0.004% S, up to 0.20% Si, 0.01-0.06% Al, up to 0.0060% N, 0.20-0.50% Cr, 0.010-0.050% Ti, 0.0010-0.0045% B and remainder iron and unavoidable impurities, is cast into a cast strip having a thickness of 1-4 mm, wherein the cast strip is hot-rolled in-line into a hot-rolled strip having a thickness of 0.5 to 3.2 mm in a continuous process at a final hot-rolling temperature ranging from 800 to 1100° C., the deformation degree being greater than 20%, and wherein the hot-rolled strip is coiled at a coiling temperature ranging from 250 to 570° C., so as to obtain a hot-rolled strip, which has a minimum tensile strength R_m of 800 MPa at a minimum breaking elongation A_{80} of 5%.

[0011] The invention provides a method of casting to convert a particularly high-tensile, possibly peritectically solidifying multi-phase steel into a hot-rolled strip. Since the cast strip itself in this case already possesses a narrow thickness, only relatively low deformation degrees must be maintained in the course of hot-rolling this strip, in order to manufacture flat products with narrow thicknesses, as they are needed particularly in the field of automotive construction. Thus it is possible with the method according to the invention, by specifying a corresponding initial thickness of the cast strip, to produce without any problems hot-rolled strip, which with an optimal characteristic distribution has a maximum thickness of 1.5 mm and from which components for the support structure of a vehicle for example can be manufactured.

[0012] Due to the low deformation degrees during hot-rolling, the rolling forces necessary for this, compared to the forces necessary for hot-rolling slabs or thin slabs with the conventional method, are low, so that hot-rolled strip of large width, which lies substantially above the width of hot-rolled strip of the same strength and thickness cast in the conventional way, can be produced without any problems with the method according to the invention. Thus, the invention permits high-tensile hot-rolled strip, consisting of a martensitic steel with the composition indicated and processed according to the invention, the width of which is greater than 1,200 mm, in particular greater than 1,600 mm, to be reliably produced.

[0013] The application according to the invention of the strip casting process for converting high-tensile steels of the type composed according to the invention, apart from the advantages mentioned above, due to their characteristics and process variables specific to the method (hot-rolling final temperature, cooling, coiling temperature for example) offers the possibility, also in respect to their solidification behavior, of reliably casting critical steel compositions of the type processed according to the invention. Thus very rapid solidification of the cast strip, characteristic of strip casting, leads to a substantially reduced risk of the emergence of center liquations, compared to conventional production, with the consequence that the hot-rolled strip produced according to the invention has a particularly uniform characteristic distribution and microstructure over its cross section and its length.

[0014] A further special advantage of the method according to the invention is that the hot-rolled strip produced according to the invention has a high strength of at least 800 MPa, without in addition a special cooling cycle of the hot-rolled strip having to be maintained between the end of hot-rolling and coiling, which is prescribed for example in EP 1 072 689 B I as the result of the need for a cooling interruption. In carrying out the method according to the invention, it must only be ensured that hot-rolling is terminated in a relatively closely confined temperature window and also that coiling is carried out in a precisely defined temperature range. Single-step cooling takes place in the interim.

[0015] A further advantage of the method according to the invention is that an extension in the range of mechanical properties of the strip produced according to the invention can be achieved, based on a single steel analysis, by varying the cooling and rolling conditions.

[0016] Hot-rolled strip produced according to the invention is particularly suitable for subsequent conversion into cold-rolled strip. Accordingly, one practical embodiment of the invention makes provision for the hot-rolled strip to be cold-rolled into cold-rolled strip having a thickness of 0.5-1.4 mm, in particular 0.7 mm up to 1.3 mm, as is needed for constructing automotive bodies. In order to eliminate solidifications arising during cold-rolling, the cold-rolled strip can be annealed at an annealing temperature of 750-850° C. For cold strip produced in this way from hot-rolled strip manufactured according to the invention, a minimum tensile strength of 800 MPa can be reliably ensured. At the same time just as reliably the minimum breaking elongation A_{50} of the cold-rolled strip is 10%.

[0017] In accordance with a further advantageous embodiment of the invention the cold-rolled strip is provided in the way known per se with a metallic coating, in which, for example, this can be a zinc coating.

[0018] The strength and elongation values of hot-rolled strip produced according to the invention can be adjusted over a large range by corresponding coordination of the final hot-rolling and coiling temperatures. If for example hot-rolled strip, which has a minimum breaking elongation A_{80} of the obtained hot-rolled strip of 10% and a minimum tensile strength R_m of 800 MPa, is to be manufactured, this can be achieved due to the final hot-rolling temperature being 900-1000° C. and the coiling temperature being 420-510° C.

[0019] On the other hand, if a hot-rolled strip with a higher tensile strength R_m of at least 1000 MPa at a minimum breaking elongation A_{80} of 5% is to be manufactured, in order to do this a final hot-rolling temperature ranging from 900 to 1100° C. and a coiling temperature ranging from 450 to 570° C. are selected.

[0020] Even higher tensile strengths R_m of the obtained hot-rolled strip of at least 1200 MPa with a minimum breaking elongation A_{80} of 5% can be achieved due to the final hot-rolling temperature being 800-1000° C. and the coiling temperature being 250-550° C.

[0021] The invention is described in detail below on the basis of exemplary embodiments.

DESCRIPTION

[0022] In trials carried out to demonstrate the effect of the invention, two steels A and B composed according to the invention with the composition indicated in Table 1 are melted and, in a conventional two-roll casting machine, cast into cast strip, which was 1.6 mm thick.

TABLE 1

(data in wt. %)

	C	Mn	P	S	Si	Al	N	Cr	Ti	B
A	0.102	1.76	0.005	0.004	0.14	0.014	0.0057	0.24	0.016	0.0027
B	0.098	1.81	0.005	0.003	0.19	0.060	0.0048	0.37	0.045	0.0044

[0023] The strips cast out of the steels A and B have been hot-rolled in-line directly after the strip was cast into a hot-rolled strip, having a thickness of 1.25 mm, at a final hot-rolling temperature WET. Subsequently, the obtained hot-rolled strip in each case was directly cooled in a cooling step to a coiling temperature HT and coiled. After coiling the hot-rolled strips produced from the steels A and B in each case had a tensile strength R_m and a breaking elongation A_{80}, which are indicated in Table 2 as the final hot-rolling temperature WET and coiling temperature HT maintained in each case during their production.

TABLE 2

Trial	Steel	WET [° C.]	HT [° C.]	R_m [MPa]	A_{80} [%]
1	B	950	500	878	11.3
2	B	1050	480	1073	5.5
3	A	830	285	1234	6.2
4	B	950	540	1041	5.3
5	B	950	510	1263	5.5
6	A	950	440	1244	5.1

[0024] The hot-rolled strip produced according to Trial 4 from steel B, after coiling and pickling, was cold-rolled into a 0.7 mm thick cold-rolled strip and annealed in-line at a temperature of 800° C., in order to recrystallize the strip.

[0025] With a breaking elongation A_{50} of 11.5%, the tensile strength R_m of the cold-rolled strip obtained in this way was 835 MPa.

1. Method for manufacturing flat steel products,

wherein a steel that forms a multi-phase microstructure with the following composition (in wt. %)

C: 0.08-0.12%

Mn: 1.70-2.00%

P:≦0.030%

S:≦0.004%

Si:≦0.20%

Al: 0.01-0.06%

N:≦0.0060%

Cr: 0.20-0.50%

Ti: 0.010-0.050%

B: 0.0010-0.0045%

remainder iron and unavoidable impurities

is cast into a cast strip having a thickness of 1-4 mm,

wherein the cast strip is hot-rolled in-line into a hot-rolled strip having a thickness ranging from 0.5 to 3.2 mm in a continuous process at a final hot-rolling temperature ranging from 800 to 1100° C., the deformation degree being greater than 20%, and

wherein the hot-rolled strip is coiled at a coiling temperature ranging from 250 to 570° C.

so as to obtain a hot-rolled strip, which has a minimum tensile strength R_m of 800 MPa at a minimum breaking elongation A_{80} of 5%.

2. Method according to claim **1**, wherein the width of the hot-rolled strip is greater than 1,200 mm.

3. Method according to claim **1**, wherein the thickness of the hot-rolled strip is 1.5 mm at most.

4. Method according to claim **1**, wherein the hot-rolled strip is cold-rolled into cold-rolled strip having a thickness of 0.5-1.4 mm.

5. Method according to claim **4**, wherein the cold-rolled strip is annealed at an annealing temperature of 750-850° C.

6. Method according to claim **4**, wherein a minimum tensile strength of the cold-rolled strip is 800 MPa.

7. Method according to claim **4**, wherein the cold-rolled strip has a minimum breaking elongation A_{50} of 10%.

8. Method according claim **1**, wherein the hot-rolled strip is provided with a metallic coating.

9. Method according to claim **8**, wherein the metallic coating is a zinc coating.

10. Method according to claim **1**, wherein with a minimum breaking elongation A_{80} of the obtained hot-rolled strip of 10%, the final hot-rolling temperature is 900-1020° C. and the coiling temperature is 420-490° C.

11. Method according to claim **1**, wherein with a minimum tensile strength R_m of the obtained hot-rolled strip of 1000 MPa, the final hot-rolling temperature is 900-1100° C. and the coiling temperature is 450-570° C.

12. Method according to claim **1**, wherein with a minimum tensile strength R_m of the obtained hot-rolled strip of 1200 MPa, the final hot-rolling temperature is 800-1000° C. and the coiling temperature is 250-550° C.

13. Method according to claim **4**, wherein the cold-rolled strip is provided with a metallic coating.

14. Method according to claim **13**, wherein the metallic coating is a zinc coating.

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