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(54) **METHOD OF PRODUCING A HOT-ROLLED TWIP-STEEL AND A TWIP-STEEL PRODUCT PRODUCED THEREBY**

VERFAHREN ZUR HERSTELLUNG EINES HEISSGEWALZTEN TWIP-STAHLS UND DADURCH GEWONNENES HEISSGEWALZTES TWIP-STAHLPRODUKT

PROCÉDÉ DE FABRICATION D'UN ACIER TWIP LAMINÉ À CHAUD ET ACIER TWIP LAMINÉ À CHAUD FABRIQUÉ SELON CE PROCÉDÉ

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(73) Proprietor: **Tata Steel IJmuiden BV**
1970 CA Ijmuiden (NL)

(72) Inventor: **CORNELISSEN, Marcus, Cornelis, Maria**
NL-1901 BZ Castricum (NL)

(74) Representative: **Bodin, Andre**
Tata Steel Nederland Technology B.V.
Group Intellectual Property Services
P.O. Box 10000 - 3G.37
1970 CA IJmuiden (NL)

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Description

[0001] This invention relates to a method for producing a hot-rolled TWIP-steel, and a TWIP-steel produced thereby.

[0002] High manganese austenitic steels combine a capacity to be drawn into very complex parts with a very high strength. TWIP steels derive their exceptional properties from a specific strengthening mechanism: twinning. In addition to the basic mechanism of dislocation gliding, deformation also occurs by twinning. The steels are fully austenitic and nonmagnetic during production at high temperatures and during use at ambient temperatures. The formation of mechanical twins during deformation generates high strain hardening, prevents necking and thus maintains a very high strain capacity. This mechanism is called **TW**inning **I**nduced **P**lasticity.

[0003] Car manufacturers devote much time, effort, and cost to developing new ways of protecting drivers and passengers. Along with the design of the car body, the steel grades used are of prime importance. TWIP-steels are particularly useful in parts of a car such as the inner parts of the A-pillar, because large deformations of the part prior to mounting in the car are required, whereas significant reduction potential must be present to act as a crash absorber in the event of an accident. In the event of an accident, the steel components must combine two different characteristics: they should be ductile to absorb most of the collision energy and at the same time have sufficient shape stability to protect the passenger cabin. In case of a crash, the TWIP-steel part is able to accommodate further deformation because of its ductility reserve. Each part of the steel elongates, then strengthens and passes on the remaining deformation energy to the surrounding parts, which then also starts to deform. Hence, by dispersing energy over the whole surface, the collision momentum is absorbed more efficiently and the passengers stay safe.

[0004] Various routes for producing TWIP steels are currently being considered. Conventional production routes involve casting of thick slabs of 200 to 400 mm in thickness. These slabs are reheated to temperatures between 1100 and 1300°C and hot-rolled to the desired hot-rolled thickness (h_f) in a plurality of rolling passes. In view of the high level of alloying elements, micro-segregation of manganese, result in low strength of the solidified shell during continuous casting and a reduction of the melting point in the interior of the slab due to the manganese enrichment. Another problem is the depletion of the alloying elements in the surface region and oxidation of the grain boundaries during the reheating of slabs in the reheating furnace of the hot-strip mills. Alternatively, strip-casting is being looked at as a source for a strip. The cast strip may be subjected to one or more hot-rolling passes after casting to achieve the desired hot-rolled thickness (h_f). This process has the disadvantage of allowing only a limited reduction in the hot-rolling process. A higher reduction is desirable to combat the effects of the segregation and local depletion of the alloying elements and to achieve a fine grain size of the hot-rolled product.

[0005] WO2004026497 and DE102005010243 disclose a method of manufacture of a hot-rolled strip of TWIP-steel using a thin slab casting and direct rolling apparatus. US5647922 discloses a method to prevent cracking of TWIP steels during the conventional thick slab casting, reheating and hot-rolling process by using a low reduction ratio during the initial stages of the hot rolling process followed by using a high reduction ratio during the final stages of the hot rolling process.

[0006] During the hot-rolling process, an oxide layer is formed on the surface of the hot-rolled strip. The hot-rolled strip has to be pickled to remove this oxide layer before cold-rolling to the final thickness. After pickling, the strip is cold-rolled to the final thickness. In the cold-rolling process the resulting cold-rolled strip becomes heavily deformed.

[0007] Prior to coating in a hot-dip coating process, the strip must be annealed to promote recrystallisation of the cold deformed microstructure to restore the formability of the steel.

[0008] During this annealing process manganese-oxide particles form on the surface of the strip. These particles adversely affect the adhesion of the metallic coating to the strip and have to be removed prior to coating. This removal requires a second pickling prior to hot-dip coating. This additional process step is economically and logistically unattractive because it increases the production costs and the risk of rejection.

[0009] It is an object of the invention to provide a method for the manufacture of a steel strip which allows a larger reduction during hot rolling.

[0010] It is also an object of this invention to provide a process for producing a coated TWIP steel in a more economical way without the risk of rejection.

[0011] One or more of the objects of the invention is reached by the method according to claim 1. The method according to the invention provides a method for the manufacture of a TWIP-steel strip, whereby molten steel having a composition comprising 0.05-0.78% C, 11 to 23% Mn, at most 5% Al, at most 5% Cr, at most 2.5% Ni, at most 5% Si, at most 0.5% V, the remainder being iron and unavoidable impurities is cast in a continuous casting machine with one or more strands to form a slab having a thickness of at least 30 mm and at most 120 mm and, while making use of the casting heat, is conveyed through a furnace apparatus, is hot-rolled in a hot-rolling mill comprising one or more rolling stands into a steel strip of a desired final thickness (h_f) of between 0.5 and 5 mm

i. in an endless rolling process wherein

a. there is a material connection between the steel in the continuous casting machine, in the furnace apparatus and the hot rolling mill and the optional forced cooling zone, or b. wherein slabs of a plurality of strands are connected so as to form a continuous slab thereby achieving a material connection between the steel in the furnace apparatus and the hot rolling mill and the optional forced cooling zone; or

ii. in a semi-endless rolling process wherein there is a material connection between the steel in the furnace apparatus and the hot rolling mill and the optional forced cooling zone,

and wherein the strip after the endless or semi-endless rolling and after the optional forced cooling is cut to portions of the desired length which are subsequently coiled.

[0012] This method allows a large reduction of the cast slab while ensuring a very homogeneous temperature over the width and thickness of the strip. The method does not relate to the so-called strip-casting process, wherein a strip of a thickness between 1 and 20 mm is. These thin strips do not allow a sufficiently large reduction of the cast slab. Moreover, as a result of the material connection it is possible to reach a small finished thickness after hot-rolling, because the head of each new coil is attached to the tail of the preceding coil, and these are only separated immediately before coiling thereby avoiding risks of lift-off of the strip from the run-out table after the hot-rolling mill. With the method in accordance with the invention the micro-segregation of alloying elements is neutralised in the furnace apparatus by diffusion. The macro-segregation is levelled out by the large deformation of the solidified slab in the hot rolling operation. This hot rolling operation may comprise a roughing operation and a separate finishing operation, but the entire rolling operation may also be performed in a rolling mill in which the roughing and finishing operation are combined. The constant rolling speed during endless or semi-endless rolling process ensures that each point of a slab has substantially the same thermomechanical history and this is a great advantage for these kinds of steels in comparison to the slab-by-slab and coil-by-coil process because the thermally activated processes such as the diffusion process to counteract the micro-segregation, the dynamic and static recrystallisation during rolling, the grain growth of the austenitic grains, the development of the crystallographic texture, precipitation reactions result in a homogeneous product. Also the rolling speed over the length of the slab is substantially constant, which is not the case in the slab-by-slab and coil-by-coil process. Many metallurgical processes such as the generation of dislocations are strain rate dependent and a constant strain rate at a constant temperature (or rather a constant reduction and rolling speed at constant temperature) results in homogeneous and reproducible properties. Since these austenitic steels do not have the benefit of a phase transformation upon cooling to room temperature the common steels have, it is particularly important to ensure a reproducible and homogenous hot-rolling process in accordance with the invention. Preferably, the microstructure of the ferrous matrix of the finished sheet has an austenite volume content of at least 75%.

[0013] After thin slab casting the slab is either directly fed to a soaking furnace to provide the slab with the correct and homogeneous (over length width and thickness of the slab) temperature for the hot-rolling step, or directly fed from the casting to the hot-rolling step with no, or only a very limited temperature correction.

[0014] During the hot-rolling process, an oxide layer is formed on the surface of the hot-rolled strip. The hot-rolled strip has to be pickled to remove this oxide layer before cold-rolling to the final thickness. After pickling, the strip is cold-rolled to the final thickness. In the conventional cold-rolling process the resulting cold-rolled strip becomes heavily deformed.

[0015] The method according to the invention comprises the steps of:

- casting a thin slab and hot-rolling the thin slab to a strip having a final thickness (hf) as described hereinabove;

- pickling the strip;

- providing the strip with a metallic coating;

[0016] The strip is subjected to a cold rolling reduction (CCR) or temper rolling reduction (TRR) between hot-rolling and coating and/or after coating. This CRR or TRR is at most 20% and the cold rolling reduction or temper rolling reduction is the only cold-rolling step between hot-rolling and coating and/or after coating of the strip. By means of this CRR the mechanical properties of the strip can be finely tuned to the requirements of the customer. In the remainder of this description TRR will be used to indicate the reduction in the cold rolling or temper-rolling reduction. Temper rolling is a cold rolling process. It is noted that a temper rolling treatment with the express and sole purpose of shape correction only is not considered to be a cold-rolling step in this respect because it does not necessitate the annealing to recrystallise the heavily deformed cold-rolled microstructure. Temper rolling treatments with the sole purpose of removing the yield point elongation are not used for these types of steel. The term temper rolling is used as an equivalent to cold rolling to a degree of reduction that does not require an annealing treatment afterwards prior to the use of the steel in a forming operation and that is not used with the express and sole purpose of shape correction only.

[0017] It should be noted that the strip may be cold reduced after coating when the steel is pressed, press-formed, deep-drawn or formed into a part for application in e.g. a car. In the context of this invention, the deformation induced by these forming presses are not to be regarded as a TRR. It should be noted that in the context of this invention the temper rolling reduction of 20% is considered to be the aggregate cold rolling reduction between the end of the hot-rolling step and the use of the steel strip in a subsequent production process such as pressing or stamping a part from a blank cut from the steel strip. The deformation of the steel by the use is not considered part of said aggregate cold rolling reduction.

[0018] The coating step is performed after the cold rolling reduction and there is no annealing step and no pickling step between the cold rolling step and the coating step.

[0019] The thin slab preferably has a thickness of at most 100 mm, and is at least 30 mm. Preferably, the thin slab thickness is between 30 and 90 mm. Since the thickness of the strip is mainly produced by hot-rolling because of the very limited or even absent cold-rolling step, it is advantageous if the thin slab thickness is as low as possible. The minimum slab thickness is limited by dimensional limitations of the thin slab casting process. So a thin slab of about 45 to 65 mm may be preferable. Liquid core reduction of the cast slab may be used to reduce the slab in thickness prior to hot-rolling. Due to the difference in metallurgical conditions, liquid core reduction in this context is deemed to be part of the casting process, and not of the hot-rolling process.

[0020] The hot-rolled thickness of the steel strip is between 0.5 and 5 mm. However, since the main application for these steels will be the replacing of cold-rolled and annealed steels, the preferable thickness range is between 0.5 and 3.0 mm. More preferably the maximum thickness is 2.5 or even 2.0 mm. A suitable minimum thickness is 0.8 mm or even 1.0 mm.

[0021] All compositional percentages are given in weight percent unless indicated otherwise. Steels of this composition were found to exhibit excellent TWIP-related properties.

[0022] To benefit from the addition of vanadium a preferably minimum vanadium content is at least 0.05%. To benefit from the addition of aluminium a preferable minimum aluminium content of the steel is at least 1 %. The aluminium content of the steel of at least 1 % ensures an increased stability of the austenite.

[0023] The alloying with vanadium will promote the formation of VC-precipitates which contribute to the strength of the steel and the prevention of delayed cracking by providing sinks for hydrogen at the predominantly semicoherent interface between the VC-precipitates and the matrix. To optimise this effect, a minimum vanadium content of 0.1 or even 0.2% is preferable. In an embodiment, the chromium content is at most 0.5% and/or at least 0.05%. A suitable minimum chromium content is 0.10 or even 0.15%.

[0024] In an embodiment of the invention, the steel sheet comprises a maximum Mn content of 18% Mn. A suitable maximum manganese content is 16% or even 15.5%.

[0025] In an embodiment the Ni and Mn contents are chosen such that (Ni+Mn) is from 11.0 to 23. A preferable maximum for (Ni+Mn) is 18%. More preferably this maximum is chosen to be 17 or even 15.9%.

[0026] In an embodiment of the invention the microstructure of the sheet comprises at least 80%, preferably at least 85%, more preferably at least 90% and even more preferably at least 95% in volume of austenite after hot rolling and cooling. Due to the metastability of the austenite, and the occurrence of transformation induced plasticity, the amount of austenite tends to decrease during subsequent processing steps. In order to ensure good formability and high strength, even during a later or its last processing step, it is desirable to have an austenite content which is as high as possible at any stage of the processing.

[0027] Prior to coating in a hot-dip coating process, the strip must be annealed to promote recrystallisation of the cold deformed microstructure to restore the formability of the steel.

[0028] During this annealing process manganese-oxide particles form on the surface of the strip. These particles adversely affect the adhesion of the metallic coating to the strip and have to be removed prior to coating. This removal requires a second pickling prior to hot-dip coating. This additional process step is economically and logistically unattractive because it increases the production costs and the risk of rejection.

[0029] The metallic coating may be provided by means of a hot-dip coating step, an electro-coating step, a physical vapour deposition step or a chemical vapour deposition step, optionally followed by a heat treatment such as galvannealing after a hot-dip galvanising step. Preferably the metallic coating layer has a thickness of at least 1 μm.

[0030] In the method according to the invention, the strip is not cold-rolled to a degree that it is necessary to anneal the strip because an adequate deformation potential is still available as a result of the TWIP-properties. Consequently, because of the absence of the annealing step the formation of the manganese-oxide particles on the surface of the strip is prevented. A second pickling prior to hot dip coating to remove these particles is thus avoided, thereby significantly reducing the production costs of the coated steel and the risk of rejection.

[0031] Usually the hot-rolled strip is coiled after rolling and uncoiled before pickling, but the invention also relates to a direct link between hot-rolling and pickling immediately followed by coating, thus saving a coiling and uncoiling step and potentially a cooling and reheating step e.g. in case of a hot-dip coating step.

[0032] By producing a coated TWIP-steel strip according to the invention the formation of particles which adversely affect the adhesion of the hot dip coating to the steel strip is prevented. It is noted that it is essential that there is no cold-rolling step between the hot rolling and the coating with a cold rolling reduction necessitating an annealing step between the pickling and the hot dip coating step because then the undesirable manganese-oxide particles will form onto the surface of the annealed strip. It is noted that a temper rolling treatment with the express and sole purpose of shape correction only is not considered to be a cold-rolling step in this respect. Temper rolling treatments with the sole purpose of removing the yield point elongation are not used for these types of steel. The maximum aggregate cold rolling reduction (or temper-rolling reduction) to be used in accordance with this invention is 20%. The aggregate cold rolling reduction is defined as the total cold rolling reduction between the end of the hot-rolling step and the use of the steel strip in a subsequent process such as blanking, forming, joining, etc. At this reduction the yield strength and to a lesser extent the tensile strength have increased considerably, but the ductility of the cold rolled product is still adequate for many forming purposes. Preferably the maximum TRR is at most 10%, more preferably 8% or even 6%. A suitable minimum value for the TRR is 0.5%, preferably 1% or even 2%. Preferably, the TRR is between 1 and 4%. This level of TRR also allows correction of the shape of the hot-rolled strip, and is preferably performed after the coating step, although it is also possible to perform the TR after pickling and prior to coating. For the purpose of effectively influencing the properties of the hot rolled strip by cold rolling, a minimum TRR of at least 5% is desirable. A suitable minimum value in that case is 8% or even 10%.

[0033] Cold-rolling in the context of this invention is defined as rolling while the material to be rolled has an absolute temperature T(K) of at most half the absolute solidus temperature of the steel. However, since the solidus temperature of TWIP steels can be very low, a suitable maximum temperature of the material to be rolled is at most 400°C, and preferably at most 200°C. Starting the cold rolling process with a material at ambient temperature causes a temperature increase of the material during cold rolling due to the deformation of the material. As said, this temperature increase should not result in a temperature of the material over 400°C or preferably not over 200°C.

[0034] In an embodiment of the invention, the coated TWIP-steel sheet is used as a replacement for cold-rolled, annealed and coated steel sheet. In order to be able to replace cold-rolled sheet, the thickness of the hot-rolled product needs to be small enough. The method as described hereinabove is particularly suitable to provide these thin hot-rolled strips with homogeneous properties without the enlarged risk of rejection due to lift-off of the heads of these strips. Said strip may be subjected to an uniform cold rolling reduction wherein the aggregate cold rolling reduction between the end of the hot-rolling step and the use of the steel strip is at most 20%.

[0035] In an embodiment of the invention, at least one part of the hot-rolled TWIP steel is subjected to a cold reduction which is different from the other parts of the hot rolled TWIP steel so as to achieve a different local thickness and/or different local mechanical properties. The cold reduced microstructure brought about by an aggregate cold rolling reduction of at most 20% between the end of the hot-rolling step and the use of the steel strip.

[0036] This embodiment allows tailoring the tensile and yield strength of different parts of the hot rolled strip. It should be noted that the cold reduction may be performed by a cold rolling step which is able to impose different cold reductions over length and/or width of the rolled product. The rolled product may be a strip, plate or sheet of steel. From this product blanks may be produced which can e.g. be used for a stamping or pressing operation.

[0037] In an embodiment the cold reduction is a step in the production of a tailor-rolled blank, and wherein the cold reduction of the various parts of the TRB is chosen such that in the cold-reduced part or parts of the TRB the desired values of mechanical properties are obtained. In this process a steel product, having an initial set of mechanical properties, is subjected to a rolling process allowing to change the degree of reduction over the length of the strip (laterally) and/or over the width of the strip (longitudinally). The degrees of reduction are chosen such so as to produce the TRB having the desired geometrical properties, but more importantly, to have the desired mechanical properties in each part of the TRB. Parts which have been subjected to a higher degree of cold reduction will possess a higher yield strength than the parts which have not been cold deformed to a smaller or no extent. The parts undergoing small reductions still have a large formability potential and can be used on the location where the TRB will be subjected to a large deformation during the production of the finished part of the TRB, whereas the more heavily cold deformed parts can be located such that they coincide with the location of the finished part where a high yield strength is required. This tuning of the mechanical properties prior to the stamping or production of the final part allows a larger flexibility of designing the final part, whereas the cold-deformation process is a more accurate way of tuning the properties than the stamping or production process of the final part. Preferably each cold reduced microstructure was brought about by an aggregate cold rolling reduction of at most 20% between the end of the hot-rolling step and the use of the steel strip.

[0038] In an embodiment of the invention, the metal coating is a conventional zinc or zinc alloy coating provided by hot dip coating or electro-coating.

[0039] In an embodiment the metal coating is a Mg-Zn alloy coating layer, wherein the zinc alloy consists of 0.3 - 4.0 %Mg and 0.05 - 6.0 % Al, optionally at most 0.2 % of one or more additional elements, unavoidable impurities and the remainder being zinc. The aluminium content is limited to 6%, because above 6% the weldability is impaired. If only one additional element is added, the maximum amount is 0.2%. If two or more additional elements are added, the maximum sum of the amounts of these additional elements is 0.2%.

[0040] In a preferable embodiment the Mg-Zn alloy comprises 0.3 - 2.3 weight % magnesium and 0.6 - 2.3 weight % aluminium more preferably wherein the zinc alloy contains 1.6 - 2.3 weight % magnesium and 1.6 - 2.3 weight % aluminium.

[0041] The inventors found that these Mg-Zn alloy coatings performed well and showed good adherence and corrosion properties throughout. These coatings have a relatively high melting point which reduces the risk of the coating to melting, flowing and fouling the hot forming tools during the heat treatment. This means that the shaped product is likely to maintain a high form and surface quality individually over the course of a production series. Moreover, the magnesium containing zinc alloy coating layer provides lubrication during the thermomechanical shaping step. In addition, the elements of the Mg-Zn alloy coating layer diffused into the steel substrate during the prolonged exposure to heat when the coated steel material was heated prior to hot forming, thereby resulting in a diffusion coating, whilst the magnesium and aluminium are oxidised. This diffusion coating already provides the steel substrate with corrosion protection, whereas it is also believed to promote the adhesion of the zinc alloy coating layer to the steel substrate. The thickness of the Zn-diffusion layer should be chosen such that active corrosion protection after the forming and cooling step is achieved. Moreover, the coating provides excellent crack closure of any cracks formed in the coating during forming, good resistance against abrasion during forming and providing good corrosion resistance prior to, during and after the thermomechanical operation, including protection of the edges of the part due to the galvanic behaviour of zinc with steel.

[0042] An additional element that could be added in a small amount to the Mg-Zn layers, less than 0.2 weight %, could be Pb or Sb, Ti, Ca, Mn, Sn, La, Ce, Cr, Ni, Zr or Bi. Pb, Sn, Bi and Sb are usually added to form spangles. These small amounts of an additional element do not alter the properties of the coating nor the bath to any significant extent for the usual applications. Preferably, when one or more additional elements are present in the zinc alloy coating, each is present in an amount < 0.02 weight %, preferably each is present in an amount < 0.01 weight %. This is because additional elements do not change the corrosion resistance to a significant extent as compared to the addition of magnesium and aluminium, and additional elements make the coated steel strip more costly. Additional elements are usually only added to prevent dross forming in the bath with molten zinc alloy for the hot dip galvanising, or to form spangles in the coating layer. The additional elements are thus kept as low as possible. The amount of zinc alloy on one side of the steel strip should be between 25 and 600 g/m^2. This corresponds to a thickness of between about 4 and 95 μm. Preferably the thickness is between 4 and 20 μm (50-140 g/m^2) because thicker coatings are not necessary for most applications. The zinc alloy coating layer according to the invention improves the protection against corrosion at a thickness of at most 12 μm. A thinner coating layer is beneficial for welding together two sheets of steel with the coating layer according to the invention, for instance by laser welding. In a preferred embodiment, the zinc alloy coating layer has a thickness of 3 - 10 μm, this being a preferred thickness range for automotive applications. According to a further preferred embodiment, the zinc alloy coating layer has a thickness of 3 - 8 μm or even 7 μm.

Claims

1. Method for the manufacture of a TWIP-steel strip, whereby molten steel having a composition comprising 0.05-0.78% C, 11 to 23% Mn, at most 5% Al, at most 5% Cr, at most 2.5% Ni, at most 5% Si, at most 0.5% V, the remainder being iron and unavoidable impurities is cast in a continuous casting machine with one or more strands to form a slab having a thickness of at least 30 mm and at most 120 mm and, while making use of the casting heat, is conveyed through a furnace apparatus, is hot-rolled in a hot-rolling mill comprising one or more rolling stands into a steel strip of a desired final thickness (h_f) of between 0.5 and 5 mm

    i. in an endless rolling process wherein

        a. there is a material connection between the steel in the continuous casting machine, in the furnace apparatus and the hot rolling mill and the optional forced cooling zone, or
        b. wherein slabs of a plurality of strands are connected so as to form a continuous slab thereby achieving a material connection between the steel in the furnace apparatus and the hot rolling mill and the optional forced cooling zone; or

    ii. in a semi-endless rolling process wherein there is a material connection between the steel in the furnace apparatus and the hot rolling mill and the optional forced cooling zone, and wherein the strip after the endless or semi-endless rolling and after the optional forced cooling is cut to portions of the desired length which are subsequently coiled,

    pickling the hot-rolled strip to remove the oxide layer formed on the surface of the hot rolled strip before cold rolling, the process also comprising the subsequent step of cold rolling the strip, wherein the aggregate cold rolling reduction between the end of the hot-rolling step and the use of the steel strip is at least 0.5% and at most 20%, and wherein a metallic coating step is performed after said subsequent cold rolling step and wherein there is no annealing step and no pickling step between the cold rolling step and the coating step.

2. Method according to claim 1 wherein the thin cast slab has a thickness of between 30 and 90 mm, and/or wherein the final thickness of the hot-rolled

and subsequently cold rolled strip is between 0.5 and 5 mm.

3. Method according to any one of claims 1 to 2, wherein the thin cast slab is produced by thin slab casting and wherein the thickness of the cast slab is at least 45 mm.

4. Method according to any one of the preceding claims wherein the metallic coating step is a hot-dip coating step, an electro-coating step, a physical vapour deposition step or a chemical vapour deposition step.

5. Method according to claim 4 wherein the hot dip coating step is a hot dip galvanizing optionally followed by a galvannealing step.

6. Method according to any one of the preceding claims wherein the aggregate cold rolling reduction between the end of the hot-rolling step and the use of the steel strip is at least 1%.

7. Method according to any one of the preceding claims wherein the aggregate cold rolling reduction between the end of the hot-rolling step and the use of the steel strip is at most 10%.

8. Method for producing a TWIP steel strip according to any one of the preceding claims for producing tailor rolled blanks.

9. Method for producing a TWIP steel strip according to any one of the preceding claims wherein the metal coating is a Mg-Zn alloy coating layer, wherein the zinc alloy consists of 0.3 - 4.0 %Mg and 0.05 - 6.0 % Al, optionally at most 0.2 % of one or more additional elements, unavoidable impurities and the remainder being zinc.

10. Method according to claim 9 wherein the Mg-Zn alloy comprises 0.3 - 2.3 weight % magnesium and 0.6 - 2.3 weight % aluminium more preferably wherein the zinc alloy contains 1.6 - 2.3 weight % magnesium and 1.6 - 2.3 weight % aluminium.

11. Coated TWIP steel strip produced according to any one of claims 1 to 10 -wherein the strip comprises a cold-reduced microstructure, and wherein the cold reduced microstructure was brought about by an aggregate cold rolling reduction of at least 0.5 and at most 20% between the end of the hot-rolling step and the use of the steel strip.

12. Coated TWIP steel strip according to claim 11 wherein the strip comprises at least two parts wherein the at least two parts comprise a different cold-reduced microstructure as a result of the at least two parts having been subjected to a different cold-rolling reduction, and wherein each cold reduced microstructure was brought about by an aggregate cold rolling reduction of at least 0.5 and at most 20% between the end of the hot-rolling step and the use of the steel strip.

13. Tailor-rolled blank produced from the strip produced according to any one of claim 11 or 12.

Patentansprüche

1. Verfahren zum Herstellen eines TWIP-Stahlstreifens, wobei geschmolzener Stahl mit einer Zusammensetzung umfassend 0,05-0,78 % C, 11 bis 23 % Mn, höchstens 5 % Al, höchstens 5 % Cr, höchstens 2,5 % Ni, höchstens 5 % Si, höchstens 0,5 % V, wobei der Rest Eisen und unvermeidbare Verunreinigungen sind, in einer Stranggussmaschine mit einem oder mehreren Strängen zur Bildung einer Bramme mit einer Dicke von mindestens 30 mm und höchstens 120 mm gegossen und unter Ausnutzung der Gusswärme durch eine Schmelzofenvorrichtung befördert, in einer Heißwalzanlage umfassend eine oder mehrere Walztische, zu einem Stahlstreifen einer gewünschten Enddicke (h_f) von zwischen 0,5 und 5 mm heißgewalzt wird

i. in einem Endloswalzprozess, wobei

a. zwischen dem Stahl in der Stranggussmaschine, in der Schmelzofenvorrichtung und Heißwalzanlage und der optionalen Zwangskühlungszone eine Materialverbindung besteht, oder
b. wobei Brammen einer Vielzahl von Strängen zur Bildung einer durchgängigen Bramme verbunden sind, so dass dadurch eine Materialverbindung zwischen dem Stahl in der Schmelzofenvorrichtung und der Heißwalzanlage und der optionalen Zwangskühlungszone erzielt wird, oder

ii. in einem Semi-Endloswalzprozess, wobei eine Materialverbindung zwischen dem Stahl in der Schmelzofenvorrichtung und der Heißwalzanlage und der optionalen Zwangskühlungszone besteht und wobei der Streifen nach dem Endlos- oder Semi-Endloswalzen und nach der optionalen Zwangskühlung in Abschnitte der gewünschten Länge, die anschließend gewickelt werden, geschnitten wird,

der heißgewalzte Streifen gebeizt wird, um die auf der Oberfläche des heißgewalzten Streifens gebildete Oxidschicht vor dem Kaltwalzen zu entfernen, wobei der Prozess auch den nachfolgenden Schritt des Kaltwalzens des Streifens umfasst, wobei die

Aggregat-Kaltwalzreduktion zwischen dem Ende des Heißwalzschritts und der Verwendung des Stahlstreifens mindestens 0,5 % und höchstens 20 % beträgt und wobei ein metallischer Beschichtungsschritt nach dem nachfolgenden Kaltwalzschritt durchgeführt wird und wobei zwischen dem Kaltwalzschritt und dem Beschichtungsschritt kein Glühschritt und kein Beizschritt erfolgt.

2. Verfahren nach Anspruch 1, wobei die dünn gegossene Bramme eine Dicke von zwischen 30 und 90 mm hat und/oder wobei die Enddicke des heißgewalzten und nachfolgend kaltgewalzten Streifens zwischen 0,5 und 5 mm beträgt.

3. Verfahren nach einem der Ansprüche 1 bis 2, wobei die dünn gegossene Bramme durch Dünnbrammenguss hergestellt wird und wobei die Dicke der gegossenen Bramme mindestens 45 mm beträgt.

4. Verfahren nach einem der vorstehenden Ansprüche, wobei der metallische Beschichtungsschritt ein Schmelztauchschritt, ein Elektrobeschichtungsschritt, ein physikalischer Dampfabscheideschritt oder ein chemischer Dampfabscheideschritt ist.

5. Verfahren nach Anspruch 4, wobei der Schmelztauchschritt eine Feuerverzinkung, gefolgt von einem optionalen Galvanisierungsschritt ist.

6. Verfahren nach einem der vorstehenden Ansprüche, wobei die Aggregat-Kaltwalzreduktion zwischen dem Ende des Heißwalzschritts und der Verwendung des Stahlstreifens mindestens 1 % beträgt.

7. Verfahren nach einem der vorstehenden Ansprüche, wobei die Aggregat-Kaltwalzreduktion zwischen dem Ende des Heißwalzschritts und der Verwendung des Stahlstreifens höchstens 10 % beträgt.

8. Verfahren zum Herstellen eines TWIP-Stahlstreifens gemäß einem der vorstehenden Ansprüche zum Herstellen individuell gewalzter Rohlinge.

9. Verfahren zum Herstellen eines TWIP-Stahlstreifens gemäß einem der vorstehenden Ansprüche, wobei die Metallbeschichtung eine Beschichtungsschicht aus Mg-Zn-Legierung ist, wobei die Zinklegierung aus 0,3 - 4,0 % Mg und 0,05 - 6,0 % Al, optional höchstens 0,2 % eines oder mehrerer zusätzlicher Elemente und unvermeidbaren Verunreinigungen besteht und wobei der Rest Zink ist.

10. Verfahren nach Anspruch 9, wobei die Mg-Zn-Legierung 0,3 - 2,3 Gew.-% Magnesium und 0,6 - 2,3 Gew.-% Aluminium umfasst, wobei die Zinklegierung weiter bevorzugt 1,6 - 2,3 Gew.-% Magnesium und 1,6 - 2,3 Gew.-% Aluminium enthält.

11. Beschichteter TWIP-Stahlstreifen, hergestellt nach einem der Ansprüche 1 bis 10, wobei der Streifen eine kaltreduzierte Mikrostruktur umfasst und wobei die kaltreduzierte Mikrostruktur durch eine Aggregat-Kaltwalzreduktion von mindestens 0,5 und höchstens 20 % zwischen dem Ende des Heißwalzschritts und der Verwendung des Stahlstreifens herbeigeführt wurde.

12. Beschichteter TWIP-Stahlstreifen nach Anspruch 11, wobei der Streifen mindestens zwei Teile umfasst, wobei die mindestens zwei Teile eine unterschiedliche kaltreduzierte Mikrostruktur umfasst, die daraus resultiert, dass die mindestens zwei Teile einer unterschiedlichen Kaltwalzreduktion unterzogen wurden und wobei jede kaltreduzierte Mikrostruktur durch eine Aggregat-Kaltwalzreduktion von mindestens 0,5 und höchstens 20 % zwischen dem Ende des Heißwalzschritts und der Verwendung des Stahlstreifens beträgt.

13. Individuell gewalzter Rohling, der aus dem nach einem der Ansprüche 11 oder 12 hergestellten Streifen hergestellt wird.

Revendications

1. Procédé destiné à la fabrication d'une bande d'acier à plasticité induite par maclage (TWIP), selon lequel de l'acier fondu, possédant une composition comprenant de 0,05 à 0,78 % de C, de 11 à 23 % de Mn, au plus 5 % d'Al, au plus 5 % de Cr, au plus de 2,5 % Ni, au plus de 5 % de Si, au plus 0,5 % de V, le reste étant du fer et des impuretés inévitables, est coulé dans une machine de coulée continue avec une ou plusieurs barres pour former une brame possédant une épaisseur supérieure ou égale à 30 mm et inférieure ou égale à 120 mm et, tout en utilisant la chaleur de coulée, étant transporté à travers un four, est laminé à chaud dans un laminoir à chaud comprenant une ou plusieurs cages de laminage en une bande d'acier d'une épaisseur finale souhaitée (h_f) comprise entre 0,5 et 5 mm

i. dans un traitement de laminage sans fin

a. une liaison de matériau étant présente entre l'acier dans la machine de coulée continue, dans le four et le laminoir à chaud et la zone de refroidissement forcé facultatif, ou

b. des brames d'une pluralité de barres étant reliées de façon à former une brame continue, obtenant ainsi une liaison de matériau entre l'acier dans le four et le laminoir à chaud et la zone de refroidissement forcé facultatif ; ou

ii. dans une traitement de laminage semi-sans fin, une liaisons de matériau étant présente entre l'acier dans le four et le laminoir à chaud et la zone de refroidissement forcé facultatif et ladite bande après le laminage semi-sans fin ou sans fin et après le refroidissement forcé facultatif, étant découpée en des parties de la longueur souhaitée qui sont ensuite bobinées,

le décapage de la bande laminée à chaud pour enlever la couche d'oxyde formée sur la surface de la bande laminée à chaud avant le laminage à froid, le traitement comprenant également l'étape suivant de laminage à froid de la bande, ladite réduction par laminage à froid globale entre la fin de l'étape de laminage à chaud et l'utilisation de la bande d'acier étant supérieure ou égale à 0,5 % et inférieure ou égale à 20 % et une étape de revêtement métallique étant effectuée après ladite étape suivante de laminage à froid et aucune étape de recuit et aucune étape décapage n'ont lieu entre l'étape de laminage à froid et l'étape de revêtement.

2. Procédé selon la revendication 1, ladite brame coulée mince possédant une épaisseur comprise entre 30 à 90 mm et/ou ladite épaisseur finale de la bande laminée à chaud et ensuite laminée à froid étant comprise entre 0,5 à 5 mm.

3. Procédé selon l'une quelconque des revendications 1 à 2, ladite brame coulée mince étant produite par le coulage de brame mince et ladite épaisseur de la brame coulée étant supérieure ou égale à 45 mm.

4. Procédé selon l'une quelconque des revendications précédentes, ladite étape de revêtement métallique étant une étape de revêtement par immersion à chaud, une étape de revêtement par électrodéposition, une étape de dépôt physique en phase vapeur ou une étape de dépôt chimique en phase vapeur.

5. Procédé selon la revendication 4, ladite étape de revêtement par immersion à chaud étant une galvanisation par immersion à chaud, éventuellement suivie par une étape de recuit après galvanisation.

6. Procédé selon l'une quelconque des revendications précédentes, ladite réduction par laminage à froid globale entre la fin de l'étape de laminage à chaud étape et l'utilisation de la bande d'acier étant supérieure ou égale à 1 %.

7. Procédé selon l'une quelconque des revendications précédentes, ladite réduction de laminage à froid globale entre la fin de l'étape de laminage à chaud et l'utilisation de la bande d'acier étant inférieure ou égale à 10 %.

8. Procédé permettant la production d'une bande d'acier TWIP selon l'une quelconque des revendications précédentes pour la fabrication d'ébauches laminées adaptées aux besoins.

9. Procédé de production d'une bande d'acier TWIP selon l'une quelconque des revendications précédentes, ledit revêtement métallique étant une couche de revêtement d'alliage de Mg-Zn, ledit alliage de zinc comprenant de 0,3 à 4,0 % de Mg et de 0,05 à 6,0 % d'Al, éventuellement au plus 0,2 % d'un ou plusieurs éléments supplémentaires, des impuretés inévitables et le reste étant du zinc.

10. Procédé selon la revendication 9, ledit alliage de Mg-Zn comprenant de 0,3 à 2,3 % en poids de magnésium et de 0,6 à 2,3 % en poids d'aluminium, de préférence l'alliage de zinc contenant de 1,6 à 2,3 % en poids de magnésium et de 1,6 à 2,3 % en poids d'aluminium.

11. Bande d'acier TWIP revêtue produite selon l'une quelconque des revendications 1 à 10, ladite bande comprenant une microstructure réduite à froid et ladite microstructure réduite à froid résultant d'une réduction par laminage à froid globale supérieure ou égale à 0,5 % et inférieure ou égale à 20 % entre la fin de l'étape de laminage à chaud et l'utilisation de la bande d'acier.

12. Bande d'acier TWIP revêtue selon la revendication 11, ladite bande comprenant au moins deux parties, lesdites au moins deux parties comprenant une microstructure réduite à froid différente à la suite des deux parties ayant été soumises à une réduction par laminage à froid différente et ladite microstructure réduite à froid résultant d'une réduction par laminage à froid globale qui est supérieure ou égale à 0,5 % et inférieure ou égale à 20 % entre la fin de l'étape de laminage à chaud et l'utilisation de la bande d'acier.

13. Ébauche laminée adaptée aux besoins produite à partir de la bande produite selon l'une quelconque des revendication 11 ou 12.

REFERENCES CITED IN THE DESCRIPTION

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