(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 114 994 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
27.03.2024 Bulletin 2024/13

(21) Application number: **21703775.3**

(22) Date of filing: **08.02.2021**

(51) International Patent Classification (IPC):
C21D 8/02 *(2006.01)* ***C21D 9/46*** *(2006.01)*
C22C 38/02 *(2006.01)* ***C22C 38/22*** *(2006.01)*
C22C 38/26 *(2006.01)* ***C22C 38/28*** *(2006.01)*
C22C 38/32 *(2006.01)* ***C22C 38/38*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
C22C 38/02; C21D 8/0205; C21D 8/0226; C21D 8/0236; C21D 8/0273; C21D 9/46; C22C 38/22; C22C 38/26; C22C 38/28; C22C 38/32; C22C 38/38; C21D 2211/002; C21D 2211/005; C21D 2211/008

(86) International application number:
PCT/IB2021/050994

(87) International publication number:
WO 2021/176285 (10.09.2021 Gazette 2021/36)

(54) HIGH STRENGTH COLD ROLLED AND GALVANNEALED STEEL SHEET AND MANUFACTURING PROCESS THEREOF

HOCHFESTES KALTGEWALZTES UND VERZINKTES STAHLBLECH UND VERFAHREN ZU SEINER HERSTELLUNG

TÔLE D'ACIER LAMINÉE À FROID À RÉSISTANCE ÉLEVÉE ET RECUITE APRÈS GALVANISATION ET SON PROCÉDÉ DE FABRICATION

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Validation States:
MA

(30) Priority: **02.03.2020 PCT/IB2020/051750**

(43) Date of publication of application:
11.01.2023 Bulletin 2023/02

(73) Proprietor: **ArcelorMittal**
1160 Luxembourg (LU)

(72) Inventors:
- **INACIO DA ROSA, Gregory**
  57000 Metz (FR)
- **ZHAO, Lijia**
  Highland, Indiana 46322 (US)
- **FAN, Dongwei**
  Munster, Indiana 46321 (US)
- **DRILLET, Josée**
  57160 Rozérieulles (FR)

(74) Representative: **Lavoix**
2, place d'Estienne d'Orves
75441 Paris Cedex 09 (FR)

(56) References cited:
US-A1- 2016 319 385 **US-A1- 2017 037 488**
US-A1- 2018 010 226

Processed by Luminess, 75001 PARIS (FR)

Description

[0001] The present invention relates to a high strength cold rolled and galvannealed steel sheet and to a method to obtain such steel sheet.

[0002] Decreasing the weight of vehicles to reduce CO2 emissions is a major challenge in the automotive industry. This weight saving must be coupled with safety requirements. To meet these requirements, an increased demand of very high strength steels with tensile strength higher than 1450MPa have led to steelmaking industry to continuously develop new grades.

[0003] These steels are usually coated with a metallic coating improving properties such corrosion resistance. The metallic coatings can be deposited by hot-dip galvanizing after the annealing of the steel sheets. To obtain an improved spot weldability, the hot dip coating can be followed by an alloying treatment to obtain a galvannealed steel sheet, so that the iron of the steel sheet diffuses towards the zinc coating in order to obtain a zinc-iron alloy on the steel sheet.

[0004] The publication WO2019188190 relates to a high strength galvanized or galvannealed steel sheet, having a tensile strength higher than 1470MPa. To obtain such a level of tensile strength, the carbon content of the steel sheet is comprised between 0.200%wt and 0.280%wt, which may reduce the weldability of the steel sheet. Moreover, the formation of ferrite and bainite, whose total amount of the sum of the two with pearlite is less than 2%, is avoided to ensure good level of tensile strength. To do so, the soaking step after cold rolling has to be performed at a temperature above Ac3.

[0005] The publication WO2016199922 relates to a high strength galvannealed steel sheet with a tensile strength higher than 1470MPa. The high amount of carbon between 0.25% and 0.70% allow to obtain this high level of tensile strength. But the weldability of the steel sheet may be reduced. After the alloying step, the steel sheet must be cooled in a controlled manner, in order to obtain at the end of the cooling, more than 10% of retained austenite. After this cooling step, the galvannealed steel sheet is subjected to a step of tempering to obtain tempered martensite, to promote bainite transformation and to cause carbon to concentrate into retained austenite, in order to obtain the desired final microstructure : between 10% and 60% of retained austenite, less than 5% of high temperature tempered martensite, less than 5% of low temperature tempered martensite, less than 10% of fresh martensite, less than 15% of ferrite, less than 10% of pearlite, the balance being bainite.

[0006] These controlled cooling and tempering steps complicate the manufacturing process. US 2016/319385 A1 discloses a high-strength galvanized steel sheet excellent in terms of spot weldability, anti-crash property, and bending formability which can preferably be used as an automotive steel sheet.

[0007] The purpose of the invention therefore is to solve the above-mentioned problem and to provide a galvannealed steel sheet having a tensile strength above or equal to1450MPa and easily processable on conventional process route.

[0008] In a preferred embodiment of the invention, the yield strength YS is above or equal to 1050MPa.

[0009] The object of the present invention is achieved by providing a steel sheet according to claim 1. The steel sheet can also comprise characteristics of anyone of claims 2 to 5. Another object is achieved by providing the method according to claim 6. The method can also comprise characteristics of anyone of claims 7 to 8.

[0010] The invention will now be described in detail and illustrated by examples without introducing limitations.

[0011] Hereinafter, Ac3 designates the temperature above which microstructure is fully austenitic, Ac1 designates the temperature above which austenite begins to form.

[0012] The composition of the steel according to the invention will now be described, the content being expressed in weight percent.

[0013] The carbon content is comprised from 0.15% to 0.25% to ensure a satisfactory strength. If the carbon content is too high, the weldability of the steel sheet is insufficient. A carbon content level below 0.15% does not make it possible to achieve a sufficient tensile strength.

[0014] The manganese content is comprised from 2.4% to 3.5% to ensure satisfactory strength and to limit bainitic transformation. Above 3.5% of addition, the risk of central segregation increases to the detriment of the ductility. An amount of at least 2.4% of manganese is mandatory in order to provide the strength and hardenability of the steel sheet as well as to stabilize austenite. Preferably, the manganese content is comprised from 2.5% to 3.2%.

[0015] According to the invention, the silicon content is comprised from 0.30% to 0.90%. Silicon is an element participating in the hardening in solid solution. A silicon addition of at least 0.30% makes it possible to obtain sufficient hardening of the ferrite and bainite. Above 0.90%, silicon oxides form at the surface, which impairs the coatability of the steel. Moreover, silicon can impair the weldability. In a preferred embodiment, the silicon content is comprised from 0.30% to 0.70%. In an other preferred embodiment, the silicon content is comprised from 0.30% to 0.50%.

[0016] According to the invention, the chromium content is comprised from 0.30% to 0.70%. Chromium is an element participating in the hardening in solid solution. A chromium content level below 0.30% does not make it possible to achieve a sufficient tensile strength. The chromium content has to be below or equal to 0.70% to obtain a satisfactory elongation at break and limit costs. According to the invention, the molybdenum content is comprised between 0.05% and 0.35%. A molybdenum addition of at least 0.05% improves the hardenability of the steel and limits bainitic transformation before and during the hot dip coating. Above 0.35%, the addition of molybdenum is costly and ineffective in view of the properties which are required. Preferably, the molybdenum content is comprised between 0.05% and 0.20%.

[0017] According to the invention, the aluminium content is comprised between 0.001% and 0.09% as it is a very effective element for deoxidizing the steel in the liquid phase during elaboration. The aluminium content is lower than 0.09% to avoid oxidation problems and ferrite formation during cooling after intercritical soaking. Preferably the aluminium amount is between 0.001% and 0.06%.

[0018] Titanium is added in an amount between 0.01% and 0.06% to provide precipitation strengthening and to protect boron against the formation of BN. According to the invention, the boron content is comprised between 0.0010% and 0.0040%. As molybdenum, boron improves the hardenability of the steel. The boron content is lower than 0.0040% to avoid a risk of breaking the slab during continuous casting. Niobium is added between 0.01% and 0.05% to refine the austenite grains during hot-rolling and to provide precipitation strengthening.

[0019] The remainder of the composition of the steel is iron and impurities resulting from the smelting. In this respect, P, S and N at least are considered as residual elements which are unavoidable impurities. Their content is less than 0.010 % for S, less than 0.020 % for P and less than 0.008 % for N.

[0020] The microstructure of the cold rolled and galvannealed steel sheet according to the invention will now be described.

[0021] After cold rolling, the cold rolled steel sheet is heated to a soaking temperature T_{soak} and maintained at said temperature for a holding time t_{soak}, both chosen in order to obtain, at the end of this intercritical soaking, a steel sheet with a microstructure consisting of between 85% and 95% of austenite and between 5% and 15% of ferrite.

[0022] A part of austenite is transformed in bainite after the cooling after the intercritical soaking, during the hot dip coating.

[0023] During the cooling step at room temperature after the galvannealing step, austenite transforms in martensite. The cold rolled and galvannealed steel sheet has a final microstructure consisting of, in surface fraction, between 80% and 90% of martensite, the balance being ferrite and bainite.

[0024] These 80% to 90% of martensite ensures a good level of tensile strength.

[0025] This martensite comprises auto tempered martensite and fresh martensite. The sum of ferrite and bainite is between 10% and 20% in order to ensure that the galvannealing step is successful.

[0026] In a preferred embodiment of the invention, the ferrite is above or equal to 5%. In an other preferred embodiment of the invention, the bainite is above or equal to 5%.

[0027] The cold rolled and galvannealed steel sheet according to the invention has a tensile strength TS above or equal to 1450 MPa. In a preferred embodiment of the invention, the yield strength YS is above or equal to 1050 MPa. TS and YS are measured according to ISO standard ISO 6892-1.

[0028] The steel sheet according to the invention can be produced by any appropriate manufacturing method and the man skilled in the art can define one. It is however preferred to use the method according to the invention comprising the following steps:

A semi-product able to be further hot-rolled, is provided with the steel composition described above. The semi product is heated to a temperature comprised from 1150°C to 1300°C, so to make it possible to ease hot rolling, with a final hot rolling temperature FRT comprises from 850°C to 950°C.

[0029] The hot-rolled steel is then cooled and coiled at a temperature Tcoil comprised from 250°C to 650°C.

[0030] After the coiling, the sheet is pickled to remove oxidation.

[0031] The steel sheet is annealed to an annealing temperature T_A comprised from 500°C and 650°C and maintaining at said temperature T_A for a holding time t_A in order to improve the cold-rollability.

[0032] After the annealing, the sheet can be pickled to remove oxidation.

[0033] The steel sheet is then cold rolled with a reduction rate between 20% and 80%, to obtain a cold rolled steel sheet, having a thickness that can be, for example, between 0.7 mm and 3 mm, or even better in the range of 0.8 mm to 2 mm. The cold-rolling reduction ratio is comprised between 20% and 80%. Below 20%, the recrystallization during subsequent heat-treatment is not favored, which may impair the ductility of the cold-rolled and galvannealed steel sheet. Above 80%, the force required to deform during cold-rolling would be too high.

[0034] The cold rolled steel sheet is then reheated to a soaking temperature T_{soak} comprised from Ac1 and Ac3 and maintained at said temperature T_{soak} for a holding time t_{soak} comprised from 30s and 200s so to obtain, at the end of this intercritical soaking, a microstructure comprising between 85% and 95% of austenite and between 5% and 15% of ferrite.

[0035] The cold rolled steel sheet is then cooled to a temperature comprised from 440°C to 480°C in order for the sheet to reach a temperature close to the coating bath, before to be coated by continuous dipping in a zinc bath at a temperature T_{Zn} comprised from 450° C to 480° C. The hot dip coated steel sheet is then reheated to a galvannealed temperature T_{GA} comprised from 510°C to 550°C, and maintained at said temperature T_{GA} for a holding time t_{GA} comprised from 10s to 30s.

[0036] The steel sheet is then cooled to room temperature to obtain a cold rolled and galvannealed steel sheet.

[0037] In a preferred embodiment of the invention, the annealing step of the hot rolled steel sheet is performed by batch in an inert atmosphere, at a heat-treating temperature T_A comprised from 500°C to 650°C and maintaining at said T_A temperature for a holding time t_A comprised from 1800s to 36000s.

[0038] In an other preferred embodiment of the invention, the annealing step of the hot rolled steel sheet is performed by continuous annealing, at a heat-treating temperature T_A comprised from 550°C to 650°C. and maintaining at said T_A temperature for a holding time t_A comprised from 30s to 100s.

[0039] The invention will be now illustrated by the following examples, which are by no way limitative.

Examples

[0040] 2 grades, which compositions are gathered in table 1, were cast in semi-products and processed into steel sheets following the process parameters gathered in table 2.

Table 1 - Compositions

The tested compositions are gathered in the following table wherein the element contents are expressed in weight percent.

Steel	C	Mn	Si	Cr	Mo	Al	Ti	B	Nb	P	S	N	Ac1(° C)	Ac3 (°C)
A	0.18	2.8	0.49	0.41	0.10	0.04	0.03	0.0022	0.02	0.01	0.002	0.004	735	805
B	0.15	2.6	0.45	0.48	0.03	0.01	0.03	0.0020	0.013	0.01	0.002	0.004	715	820

Steel A is according to the invention. Steel B out of the invention
Underlined values: not corresponding to the invention

[0041] For a given steel, Ac1 and Ac3 are measured through dilatometry tests and metallography analysis.

Table 2 - Process parameters

Steel semi-products, as cast, were reheated to 1200°C, hot rolled with finish rolling temperature FRT of 910°C, coiled at a temperature T_{coil} of 550°C. Some steel sheets are first annealed to a temperature T_A of 600°C, and maintained at said T_A temperature for a holding time t_A before to be pickled. Steel sheets are then cold rolled at a reduction rate of 45%. The cold rolled steel sheets are reheated to a soaking temperature T_{soak} and maintained at said temperature during t_{soak}, and coated by hot dip coating in a zinc bath at temperature T_{Zn} of 460°C, followed by galvannealing, with a galvannealed temperature T_{GA} comprised from 510°C to 550°C and maintained at said temperature during t_{GA} of 20s. The following specific conditions were applied:

Trials	Steel	Annealing	Soaking		Galvannealing
		T_A(°C)	T_{soak}(°C)	t_{soak}(S)	T_{GA}(°C)
1	A	600	790	180	540
2	A	600	790	138	520
3	A	600	843	138	520
4	A	600	810	138	520
5	B	-	790	180	520

Underlined values: not corresponding to the invention

[0042] The cold rolled steel sheets were analyzed after soaking and the corresponding microstructure elements were gathered in table 3.

Table 3: Microstructure of the cold rolled steel sheets after soaking

Trials	Austenite (%)	Ferrite (%)
1	94	6
2	94	6

(continued)

Trials	Austenite (%)	Ferrite (%)
3	100	0
4	100	0
5	90	10
Underlined values: not corresponding to the invention		

[0043] In order to quantify this microstructure at the end of the soaking, the steel sheets are quenched after the soaking to transform 100% of austenite in martensite, austenite being instable at room temperature. Martensite amount thus corresponds to the austenite amount at the end of the soaking. Martensite and ferrite amounts are then quantified through image analysis.

[0044] The cold rolled and galvannealed steel sheets were then analyzed and the corresponding microstructure elements and properties were respectively gathered in table 4 and 5.

Table 4: Microstructure of the cold rolled and qalvannealed steel sheets

Trials	Martensite (%)	Ferrite + Bainite (%)	Ferrite (%)	Bainite (%)
1	85	15	5	10
2	89	11	5	6
3	98	2	0	2
4	92	8	0	8
5	75	25	15	10
Underlined values: not corresponding to the invention				

[0045] The surface fractions are determined through the following method: a specimen is cut from the cold-rolled and galvannealed steel sheet, polished and etched with a reagent (Nital), to reveal the microstructure. The determination of the surface fraction of each constituent are performed with image analysis through optical microscope: Martensite has a darker contrast than ferrite and bainite. Bainite is quantified by measuring the difference of martensite fractions of the sample quenched after soaking and of the sample cooled after galvannealing. The bainite is identified thanks to the carbides inside this bainite.

Table 5: Properties of the cold rolled and galvannealed steel sheets

Trials	TS (MPa)	YS (MPa)	Success of GA
1	1522	1095	Yes
2	1634	1055	Yes
3	1519	1163	No
4	1611	1096	No
5	1363	954	Yes
Underline values: Insufficient TS or YS, or fail of the galvannealing step.			

[0046] The success of the galvannealing step is checked by measuring the amount of iron in the coating. The steel is galvannealed if the iron content in the coating is between 7% and 12%.

[0047] The examples show that the steel sheet according to the invention, namely examples 1 and 2 are the only one to show all the targeted mechanical properties with success of the galvannealing, thanks to their specific composition and microstructures. The mechanical properties are ensured thanks to the martensite between 80% and 90%. The galvannealing step is ensured thanks to the presence of ferrite and bainite in a total comprised between 10% and 20%.

[0048] In trials 3 and 4 steel A is heated above a temperature T_{soak} ensuring between 85% and 95% of austenite and between 5% and 15% of ferrite at the end of the soaking, thus forming too many austenite and not enough ferrite. This leads to the formation of less than 10% of the sum of ferrite and bainite at the end of the hot dip coating, which hinder the galvannealing step.

[0049] In Trial 5, the absence of molybdenum, which is a hardening element delaying the bainitic transformation, leads to the formation of 25% of the sum of ferrite and bainite at the end of the hot dip coating. Then, martensite formed during the last cooling step is less than 80% which leads to a low value of mechanical properties.

Claims

1. A cold rolled and galvannealed steel sheet having a chemical composition comprising, in weight %:

   C: 0.15-0.25%
   Mn: 2.4 -3.5%
   Si: 0.30-0.90%
   Cr: 0.30-0.70%
   Mo: 0.05-0.35%
   Al: 0.001-0.09%
   Ti: 0.01-0.06%
   B: 0.0010-0.0040%
   Nb 0.01-0.05%
   P≤0.020%
   S≤0.010%
   N≤0.008%

   the remainder of the composition being iron and unavoidable impurities resulting from the smelting, said steel sheet having a microstructure consisting of, in surface fraction:

   - from 80% to 90% of martensite,
   - the balance being ferrite and bainite.

2. A cold rolled and galvannealed steel sheet according to claim 1, wherein the ferrite is above or equal to 5%.

3. A cold rolled and galvannealed steel sheet according to claim 1, wherein the bainite is above or equal to 5%.

4. A cold rolled and galvannealed steel sheet according to any one of claims 1 to 3, wherein the silicon content is comprised between 0.30% and 0.70%.

5. A process for manufacturing a cold rolled and galvannealed steel sheet comprising the following and successive steps:

   - casting a steel to obtain a semi-product, said semi product having a composition according to claim 1,
   - reheating the slab to a temperature T_{reheat} comprised from 1150°C to 1300°C,
   - hot rolling the reheated slab with a final rolling temperature comprised from 850°C to 950°C, so to obtain a hot rolled steel sheet, then
   - cooling said steel sheet to a coiling temperature T_{coil} comprised from 250°C to 650°C, then
   - coiling the steel sheet at said temperature T_{coil} so to obtain a coiled steel sheet, then
   - pickling the steel sheet
   - annealing the steel sheet to an annealing temperature T_A comprised from 500°C to 650°C and maintaining the steel sheet at said temperature T_A for a holding time t_A
   - optionally pickling the steel sheet
   - cold rolling the hot-rolled steel sheet with a reduction rate between 20% and 80%, to obtain a cold rolled steel sheet,
   - heating the cold rolled steel sheet to a soaking temperature T_{soak} comprised from Ac1 to Ac3 and maintaining the steel sheet at said temperature T_{soak} for a holding time t_{soak} comprised from 30s to 200s, in order to obtain between 85% and 95% of austenite and between 5% and 15% of ferrite,
   - cooling the steel sheet to a temperature comprised from 440°C to 480°C,
   - coating the steel sheet by continuous dipping in a zinc bath at a temperature Tzn comprised from 450°C to 480°C,

- reheating the steel sheet to a galvannealed temperature T_{GA} comprised from 510°C and 550°C, and maintaining the steel sheet at said temperature T_{GA} for a holding time t_{GA} comprised from 10s and 30s
- cooling the reheated steel sheet to room temperature to obtain a cold rolled and galvannealed steel sheet.

6. A process for manufacturing a cold rolled and galvannealed steel sheet according to claim 5, wherein said annealing of the hot rolled steel sheet is performed by batch in an inert atmosphere, at a heat-treating temperature T_A comprised from 500°C to 650°C, the duration t_A at said annealing temperature being comprised from 1800s to 36000s.

7. A process for manufacturing a cold rolled and galvannealed steel sheet according to claim 5, wherein said annealing of the hot rolled steel sheet is performed by continuous annealing, at a heat-treating temperature T_A comprised from 550°C to 650°C, the duration t_A at said annealing temperature being comprised from 30s to 100s.

Patentansprüche

1. Kaltgewalztes und galvannealtes Stahlblech, das eine chemische Zusammensetzung aufweist, umfassend in Gewichtsprozent:

C: 0,15 - 0,25 %
Mn: 2,4 - 3,5 %
Si: 0,30 - 0,90 %
Cr: 0,30 - 0,70 %
Mo: 0,05 - 0,35 %
Al: 0,001 - 0,09 %
Ti: 0,01 - 0,06 %
B: 0,0010 - 0,0040 %
Nb 0,01-0,05 %
P ≤ 0,020 %
S ≤ 0,010 %
N ≤ 0,008 %

wobei der Rest der Zusammensetzung aus Eisen und unvermeidlichen Verunreinigungen aus der Verhüttung besteht, das Stahlblech eine Mikrostruktur aufweist, das in Oberflächenfraktion aus Folgendem besteht:

- von 80 % bis 90 % Martensit,
- der Rest ist Ferrit und Bainit.

2. Kaltgewalztes und galvannealtes Stahlblech nach Anspruch 1, wobei der Ferritgehalt über oder gleich 5 % ist.

3. Kaltgewalztes und galvannealtes Stahlblech nach Anspruch 1, wobei der Bainitgehalt über oder gleich 5 % ist.

4. Kaltgewalztes und galvannealtes Stahlblech nach einem der Ansprüche 1 bis 3, wobei der Silikongehalt zwischen 0,30 % und 0,70 % liegt.

5. Verfahren zum Herstellen eines kaltgewalzten und galvannealten Stahlblechs, umfassend die folgenden aufeinanderfolgenden Schritte:

- Gießen eines Stahls, um ein Halbzeug zu erhalten, wobei das Halbzeug eine Zusammensetzung gemäß Anspruch 1 aufweist,
- Wiedererhitzen der Bramme auf eine Temperatur T_{reheat} von 1150 °C bis 1300 °C,
- Warmwalzen der wiedererhitzten Bramme mit einer abschließenden Walztemperatur, die zwischen 850 °C und 950 °C liegt, um ein warmgewalztes Stahlblech zu erhalten, dann
- Abkühlen des Stahlblechs auf eine Wickeltemperatur T_{coil} von 250 °C bis 650 °C, dann
- Wickeln des Stahlblechs bei der Temperatur T_{coil}, um ein gewickeltes Stahlblech zu erhalten, dann
- Beizen des Stahlblechs,
- Glühen des Stahlblechs auf eine Glühtemperatur T_A von 500 °C bis 650 °C und Halten des Stahlblechs bei der Temperatur T_A für eine Haltezeit t_A,

- optionales Beizen des Stahlblechs,
- Kaltwalzen des warmgewalzten Stahlblechs mit einem Reduktionsgrad zwischen 20 % und 80 %, um ein kaltgewalztes Stahlblech zu erhalten,
- Erhitzen des kaltgewalzten Stahlblechs auf eine Tränktemperatur T_{soak} , die zwischen Ac1 und Ac3 liegt, und Halten des Stahlblechs bei der Temperatur T_{soak} während einer Haltezeit t_{soak} , die zwischen 30 s und 200 s liegt, um zwischen 85 % und 95 % Austenit und zwischen 5 % und 15 % Ferrit zu erhalten,
- Abkühlen des Stahlblechs auf eine Temperatur zwischen 440 °C und 480 °C,
- Beschichten des Stahlblechs durch kontinuierliches Eintauchen in ein Zinkbad bei einer Temperatur T_{Zn} von 450 °C bis 480 °C,
- Wiedererwärmen des Stahlblechs auf eine Galvannealungsttemperatur T_{GA} von 510 °C bis 550 °C und Halten des Stahlblechs bei der Temperatur T_{GA} für eine Haltezeit t_{GA} von 10 s bis 30 s.
- Abkühlen des wiedererhitzten Stahlblechs auf Raumtemperatur, um ein kaltgewalztes und galvannealtes Stahlblech zu erhalten.

6. Verfahren zum Herstellen eines kaltgewalzten und galvannealten Stahlblechs nach Anspruch 5,

wobei das Glühen des warmgewalzten
Stahlblechs chargenweise in einer inerten Atmosphäre bei einer Wärmebehandlungstemperatur T_A von 500 °C bis 650 °C ausgeführt wird, wobei die Dauer t_A bei der Glühtemperatur zwischen 1800 s und 36000 s liegt.

7. Verfahren zum Herstellen eines kaltgewalzten und galvannealten Stahlblechs nach Anspruch 5, wobei das Glühen des warmgewalzten Stahlblechs durch kontinuierliches Glühen bei einer Wärmebehandlungstemperatur T_A von 550 °C bis 650 °C erfolgt, wobei die Dauer t_A bei der Glühtemperatur zwischen 30s und 100 s liegt.

Revendications

1. Tôle d'acier laminée à froid et galvanisée ayant une composition chimique comprenant, en % en poids :

C : de 0,15 à 0,25 %
Mn : de 2,4 à 3,5 %
Si : de 0,30 à 0,90 %
Cr : de 0,30 à 0,70 %
Mo : de 0,05 à 0,35 %
Al : de 0,001 à 0,09 %
Ti : de 0,01 à 0,06 %
B : de 0,0010 à 0,0040 %
Nb de 0,01 à 0,05 %
P $\leq$ 0,020 %
S $\leq$ 0,010 %
N $\leq$ 0,008 %

le reste de la composition étant du fer et des impuretés inévitables résultant de la fusion, ladite tôle d'acier ayant une microstructure constituée, en fraction de surface :

- de 80 à 90 % de martensite,
- le reste étant constitué de ferrite et de bainite.

2. Tôle d'acier laminée à froid et galvanisée selon la revendication 1, dans laquelle la ferrite est supérieure ou égale à 5 %.

3. Tôle d'acier laminée à froid et galvanisée selon la revendication 1, dans laquelle la bainite est supérieure ou égale à 5 %.

4. Tôle d'acier laminée à froid et galvanisée selon l'une quelconque des revendications 1 à 3, dans laquelle la teneur en silicium est comprise entre 0,30 % et 0,70 %.

5. Procédé de fabrication d'une tôle d'acier laminée à froid et galvanisée, comprenant les étapes successives suivantes :

- coulée d'un acier pour obtenir un semi-produit, ce semi-produit ayant une composition selon la revendication 1,
- réchauffement de la brame à une température T_{reheat} comprise entre 1 150 °C et 1 300 °C,
- laminage à chaud de ladite brame réchauffée à une température de laminage finale comprise entre 850 °C et 950 °C, de façon à obtenir une tôle d'acier laminée à chaud, puis
- refroidissement de ladite tôle d'acier à une température d'enroulement T_{coil} comprise entre 250°C et 650°C, puis
- enrouler la tôle d'acier à ladite température T_{coil} afin d'obtenir une tôle d'acier enroulée, puis
- décapage de la tôle d'acier
- recuit de la tôle d'acier à une température de recuit T_A comprise entre 500°C et 650°C et maintien de la tôle d'acier à ladite température T_A pendant un temps de maintien t_A
- décapage éventuel de la tôle d'acier
- laminage à froid de la tôle d'acier laminée à chaud avec un taux de réduction compris entre 20 et 80 %, de manière à obtenir une tôle d'acier laminée à froid,
- chauffage de la tôle d'acier laminée à froid à une température de trempage T_{soak} comprise entre Ac1 et Ac3 et maintenir la tôle d'acier à ladite température T_{soak} pendant un temps de maintien t_{soak} compris entre 30 s et 200 s, afin d'obtenir entre 85 et 95 % d'austénite et entre 5 et 15 % de ferrite,
- refroidissement de la tôle d'acier à une température comprise entre 440 °C et 480 °C,
- revêtement de la tôle d'acier par immersion continue dans un bain de zinc à une température T_{Zn} comprise entre 450 °C et 480 °C,
- réchauffage de la tôle d'acier à une température T_{GA} de galvanisation comprise entre 510°C et 550°C, et maintien de la tôle d'acier à cette température T_{GA} pendant un temps de maintien t_{GA} compris entre 10 s et 30 s
- refroidissement de la tôle d'acier réchauffée jusqu'à la température ambiante pour obtenir une tôle d'acier laminée à froid et galvanisée.

6. Procédé de fabrication d'une tôle d'acier laminée à froid et galvanisée selon la revendication 5,

dans lequel ledit recuit de ma feuille d'acier laminée à chaud
est effectué par lot dans une atmosphère inerte, à une température de traitement thermique T_A comprise entre 500 °C et 650 °C, la durée t_A à ladite température de recuit étant comprise entre 1 800 s et 36 000 s.

7. Procédé de fabrication d'une tôle d'acier laminée à froid et galvanisée selon la revendication 5, dans lequel ledit recuit de la tôle d'acier laminée à chaud est effectué par un recuit continu, à une température de traitement thermique T_A comprise entre 550 °C et 650 °C, la durée t_A à ladite température de recuit étant comprise entre 30 s et 100 s.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2019188190 A **[0004]**
- WO 2016199922 A **[0005]**
- US 2016319385 A1 **[0006]**