



(11)

EP 4 163 411 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
12.04.2023 Bulletin 2023/15

(51) International Patent Classification (IPC):
C23C 2/06 (2006.01) C23C 2/26 (2006.01)

(21) Application number: **20940134.8**

(86) International application number:
PCT/CN2020/121167

(22) Date of filing: **15.10.2020**

(87) International publication number:
WO 2021/248765 (16.12.2021 Gazette 2021/50)

(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 Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(30) Priority: **08.06.2020 CN 202010513855**

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(54) **HOT-DIPPED ZINC-ALUMINUM-MAGNESIUM COATED STEEL SHEET AND MANUFACTURING METHOD THEREFOR**

(57) Disclosed by content of the present disclosure is a hot-dipped zinc-aluminum-magnesium coated steel sheet having cut corrosion resistance, comprising a steel sheet and a coating; the mass percents of chemical components of the coating are: aluminum, 2%-12%, magnesium, 1%-4%, and the remainder being zinc and unavoidable impurities; also, the mass percent of the aluminum is 2-3 times the mass percent of the magnesium; and the thickness of the coating is not less than 5% the thickness of the steel sheet. Further disclosed by content of the present disclosure is a preparation method for the coated steel sheet: utilizing the chemical components of the coating and obtaining a coating liquid; preheating the coating liquid and obtaining a preheated coating liquid, the temperature of the preheated coating liquid not being lower than the melting point of the coating liquid and not being higher than 500°C; obtaining a steel sheet, dipping the steel sheet into the preheated coating liquid, and obtaining a steel sheet having a coating; and lastly cooling the steel sheet having the coating. The provided preparation method allows for a cut location on a steel sheet

to be amply covered by a solution, and a dense hydroxide double layered compound is formed, causing the hot dipped zinc-aluminum-magnesium coated steel sheet to have uniquely superior cut corrosion resistance.

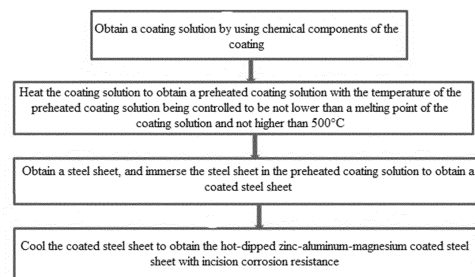


FIG. 2

EP 4 163 411 A1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present disclosure claims the priority to Chinese patent application No. CN202010513855.X, filed on June 8, 2020, entitled "HOT-DIPPED ZINC-ALUMINUM-MAGNESIUM COATED STEEL SHEET WITH EXCELLENT INCISION CORROSION RESISTANCE AND MANUFACTURING METHOD THEREFOR", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of steel manufacturing, in particular to a hot-dipped zinc-aluminum-magnesium coated steel sheet and manufacturing method therefor.

BACKGROUND

[0003] Hot-dip galvanizing involves a reaction of molten zinc and alloys thereof with a steel substrate to form a strong metallurgically bonded coating. Such hot-dip galvanized steel has the advantages of strong coating adhesion, long service life, simple manufacturing process, and low product price, and is increasingly in demand in various industries such as the automobile industry, electrical industry and construction industry.

[0004] Common hot-dip galvanized hot-rolled steel sheet comprises a zinc-only coating. With the increase in corrosion resistance requirement for the hot-dip galvanized hot-rolled steel sheet, the conventional zinc-coated steel sheet has been unable to meet the requirement for the corrosion resistance. Therefore, a hot-dipped zinc-aluminum-magnesium alloy coated steel sheet has been developed.

[0005] Although the zinc-aluminum-magnesium alloy coating has good corrosion resistance, it is found in use that when the thickness of the steel sheet is thick, corrosion is likely to occur at the incision position of the steel sheet, which is difficult to meet the needs of use. In addition, in some harsh working environments, the incision position is prone to rust, so an optimized design of the product is required.

[0006] Therefore, how to develop a hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance has become an urgent technical problem to be solved.

SUMMARY

[0007] In order to overcome the defect in the prior art, the present disclosure provides a hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance and manufacturing method therefor. The manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance provided by the present disclosure is beneficial for the steel sheet forming a liquid film containing magnesium ion, aluminum ion and zinc ion with good fluidity on the surface in the early stage of atmospheric corrosion, such that the liquid film can fully cover the steel sheet at the incision position and a dense double-layer of hydroxide compound is formed, thereby obtaining the hot-dipped zinc-aluminum-magnesium coated steel sheet with excellent incision corrosion resistance.

[0008] In one aspect of the present disclosure, a hot-dipped zinc-aluminum-magnesium coated steel sheet is provided, which may include a steel sheet and a coating, characterized in that, mass fractions of chemical components in the coating are: 2%~12% for aluminum, 1%~4% for magnesium, and rest being zinc and inevitable impurities; the mass fraction of aluminum is 2 to 3 times the mass fraction of magnesium; and a thickness of the coating is not less than 5% of a thickness of the steel sheet.

[0009] In some embodiments, the mass fraction of aluminum may be 2.3 times the mass fraction of magnesium.

[0010] In some embodiments, the thickness of the steel sheet may range from 0.5 mm to 6 mm.

[0011] In some embodiments, the mass fractions of magnesium and aluminum in the coating may be controlled based on the thickness of the steel sheet, specifically including: when $0.5 \text{ mm} \leq \text{the thickness of the steel sheet} \leq 2 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $2 \text{ mm} < \text{the thickness of the steel sheet} \leq 4 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 3% ~ 12% for aluminum, 1.5% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $4 \text{ mm} < \text{the thickness of the steel sheet} \leq 5 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 4% ~ 12% for aluminum, 2% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; and when $5 \text{ mm} < \text{the thickness of the steel sheet} \leq 6 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 6% ~ 12% for aluminum, 3% ~ 4% for magnesium, and the rest being zinc and inevitable impurities.

[0012] In another aspect of the present disclosure, a hot-dipped zinc-aluminum-magnesium coated steel sheet with

incision corrosion resistance is provided, which includes a steel sheet and a coating; mass fractions of chemical components in the coating may be: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, 0.01% ~ 0.1% for calcium, and rest being zinc and inevitable impurities; the mass fraction of aluminum may be 2 to 3 times the mass fraction of magnesium; and a thickness of the coating may be not less than 5% of a thickness of the steel sheet.

[0013] In some embodiments, when the mass fraction of calcium is 0.01%, the mass fractions of magnesium and aluminum in the coating may be controlled based on the thickness of the steel sheet, specifically including: when $0.5 \text{ mm} \leq$ the thickness of the steel sheet $\leq 2.5 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $2.5 \text{ mm} <$ the thickness of the steel sheet $\leq 4 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 2.5% ~ 12% for aluminum, 1.2% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $4 \text{ mm} <$ the thickness of the steel sheet $\leq 5 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 3.8% ~ 12% for aluminum, 1.8% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; and when $5 \text{ mm} <$ the thickness of the steel sheet $\leq 6 \text{ mm}$, the mass fractions of the chemical components in the coating may be: 5% ~ 12% of aluminum, 2.5% ~ 4% for magnesium, and the rest being zinc and inevitable impurities.

[0014] In yet another aspect of the present disclosure, a manufacture method of a hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance is provided, characterized in that, the manufacture method may include: obtaining a coating solution by using chemical components of a coating of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance; heating the coating solution to obtain a preheated coating solution with a temperature of the preheated coating solution being controlled to be not lower than a melting point of the coating solution and not higher than 500°C ; obtaining a steel sheet and immersing the steel sheet in the preheated coating solution to obtain a coated steel sheet; and cooling the coated steel sheet to obtain the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance.

[0015] In some embodiments, the cooling the coated steel sheet may include: when a temperature of the coated steel sheet is between a temperature of the coating bath and 360°C , cooling may be performed at a first cooling rate and the first cooling rate may be controlled at: $0 < \text{the first cooling rate} \leq 1^{\circ}\text{C/s}$; when the temperature of the coated steel sheet is between 360°C and 300°C , cooling may be performed at a second cooling rate and the second cooling rate may be $\geq 5^{\circ}\text{C/s}$.

[0016] In some embodiments, the cooling the coated steel sheet may include: blowing air or spraying water on the surface of the coating of the coated steel sheet for cooling.

[0017] In some embodiments, the steel sheet may be preheated to a steel sheet preheating temperature before the immersion of the steel sheet in the coating solution for bathing. The range of the steel sheet preheating temperature is the temperature of the preheated coating solution $\pm 10^{\circ}\text{C}$.

[0018] In some embodiments, the steel sheet may be preheated to the steel sheet preheating temperature before the immersion of the steel sheet in the coating solution for bathing, and the steel sheet preheating temperature is controlled based on the thickness of the steel sheet, specifically including: when $0.5 \text{ mm} \leq$ the thickness of the steel sheet $\leq 2 \text{ mm}$, the temperature of the preheated coating solution $\leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution $+ 10^{\circ}\text{C}$; when $2 \text{ mm} <$ the thickness of the steel sheet $\leq 4 \text{ mm}$, the temperature of the preheated coating solution $- 5^{\circ}\text{C} \leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution; when $4 \text{ mm} <$ the thickness of the steel sheet $\leq 6 \text{ mm}$, the temperature of the preheated coating solution $- 10^{\circ}\text{C} \leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution $- 5^{\circ}\text{C}$.

[0019] In some embodiments, the obtaining the steel sheet may include: obtaining the steel sheet with a surface roughness Ra of $1 \text{ }\mu\text{m} \sim 2 \text{ }\mu\text{m}$.

[0020] One or more technical solutions according to the embodiments of the present disclosure have at least the following technical effects or advantages: the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance and the manufacturing method thereof provided by the present disclosure include: (1) in terms of chemical components, 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities, wherein the content of aluminum in mass fraction is 2 to 3 times that of magnesium and the thickness of the coating is not less than 5% of the thickness of the steel sheet; and (2) in terms of process, the temperature of the preheated coating solution is controlled to be not lower than the melting point of the coating solution and not higher than 500°C , which is beneficial for the steel sheet forming the liquid film containing magnesium ion, aluminum ion and zinc ion with good fluidity on the surface in the early stage of atmospheric corrosion, such that the liquid film can fully cover the steel sheet at the incision position and a dense double-layer of hydroxide compound is formed, thereby obtaining the hot-dipped zinc-aluminum-magnesium coated steel sheet with excellent incision corrosion resistance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] In order to illustrate the technical solutions in the embodiments of the present disclosure more clearly, the following briefly introduces the accompanying drawings used in the description of the embodiments. Obviously, the

accompanying drawings in the following description are some examples of the present disclosure. For those of ordinary skill in the art, other drawings can also be obtained from these drawings without any creative effort.

FIG. 1 is a flow chart illustrating the protection of an incision by a zinc-aluminum-magnesium coating according to an embodiment of the present disclosure.

FIG. 2 is a flow chart illustrating the manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0022] The present disclosure will be described in detail below with reference to specific embodiments and examples, and the advantages and various effects of the present disclosure will be more clearly presented therefrom. It should be understood by those skilled in the art that these specific embodiments and examples are used to illustrate, but not to limit, the present disclosure.

[0023] The terms used throughout the specification are to be understood as commonly used in the art, unless specifically stated otherwise. Therefore, unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the present disclosure belongs. In case of conflict, the present specification takes precedence.

[0024] Unless otherwise specified, various raw materials, reagents, instruments and equipment, etc. used in the present disclosure are commercially available or can be obtained by existing methods.

[0025] An embodiment of the present disclosure provides a hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance, the general idea of which is as follows.

[0026] In order to overcome the defect in the prior art, an embodiment of the present disclosure provides a hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance, which may include a steel sheet and a coating; a mass percentage of chemical components in the coating may be: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and rest being zinc and inevitable impurities; the content of aluminum in mass fraction may be 2 to 3 times that of magnesium; and a thickness of the coating may be not less than 5% of a thickness of the steel sheet.

[0027] In some embodiments of the present disclosure, FIG. 1 illustrates a flow chart of incision protection by a zinc-aluminum-magnesium coating. In the early stage of atmospheric corrosion, water vapor in the atmosphere condenses on the surface of the coating to form a water film; the magnesium element in the coating first undergoes an anodic corrosion reaction and form magnesium ions, which are dissolved in the water film; and the magnesium ions combine with hydroxide and carbonate groups formed by a cathodic reaction to form compounds such as magnesium carbonate and basic magnesium carbonate with good fluidity. In addition, the aluminum and zinc in the coating also undergo the anodic corrosion reaction to form aluminum ions and zinc ions dissolved in the liquid film. These compounds containing magnesium ions and aluminum ions flow with the liquid film to the incision position of the steel sheet. Due to the presence of magnesium ions and aluminum ions, the pH value in the liquid film will not exceed 10, so that zinc ions will not form loose and porous zinc oxide, but tend to form dense oxides such as basic zinc carbonate and basic zinc chloride. These compounds, in turn, form a dense protective hydroxide double-layer with magnesium carbonate and aluminum hydroxide, etc., which provides a good protective effect on the incision. However, in order for the incision position of the steel sheet to be covered by these protective layers, it is required to the steel sheet form a liquid film containing magnesium ion, aluminum ion and zinc ion with good fluidity on the surface in the early stage of atmospheric corrosion, such that the liquid film can fully cover the steel sheet at the incision position and a dense double-layer of hydroxide compound is formed.

[0028] In some embodiments of the present disclosure, the reason why the mass fraction of magnesium can be set as 1% ~ 4% is that: first, a certain amount of magnesium is required in the coating and the main function of magnesium is to make the steel sheet form an aqueous solution or a liquid film with good fluidity on the surface in the early stage of atmospheric corrosion. On the one hand, this aqueous solution or the liquid film containing magnesium ions can accelerate the dissolution of aluminum and zinc to form aluminum ions and zinc ions; on the other hand, it prevents aluminum ions and zinc ions in solution from rapidly precipitating into loose compounds, instead, the solution containing the aluminum ion and zinc ion is allowed to react slowly with carbon dioxide and the like in the atmosphere to form dense oxides. If the magnesium content in the coating layer is less than 1%, this effect cannot be exhibited. However, if the magnesium content is too high, it is easy to form too thick magnesium oxide on the surface, which is not conducive to the dissolution of aluminum and zinc. At the same time, it is easy to form Mg-Zn compound hard particles that are embedded in the coating and cause electrochemical corrosion effect and thus reduce the corrosion resistance of the coating. Therefore, the magnesium content should not exceed 4%.

[0029] In some embodiments of the present disclosure, the reason why the mass fraction of aluminum can be set as 2% ~ 12% is that: the content of aluminum in the coating layer should not be less than 2%, since aluminum is the main framework element for forming the bilayer compound and is also the main element that fills the voids of loose zinc oxide and zinc hydroxide. If the aluminum content is too high, it will cause a severe galvanic corrosion effect, and a corrosion

current will be formed between aluminum and zinc, which reduces the corrosion resistance of the coating. The maximum aluminum content in the coating is 12%.

[0030] In some embodiments of the present disclosure, the reason why the content of aluminum in mass fraction may be 2 to 3 times the mass fraction of magnesium is that: in the early stage of atmospheric corrosion, the water vapor in the atmosphere condenses into the surface of the coating and form a water film. The magnesium element in the coating first undergoes an anodic reaction to form magnesium ions dissolved in the water film, and the magnesium ions combine with the hydroxide and carbonate formed by the cathodic reaction to produce basic magnesium carbonate $\text{Mg}(\text{OH})_2 \cdot \text{MgCO}_3$ and magnesium hydroxide $\text{Mg}(\text{OH})_2$. Due to the presence of magnesium ions and aluminum ions, the pH value in the water film will not exceed 10, so that zinc ions will not form loose and porous zinc oxide, but tend to form dense oxides such as basic zinc carbonate and basic zinc chloride. These compounds, in turn, form a dense protective hydroxide double-layer with magnesium carbonate and aluminum hydroxide, etc., which provides a good protective effect on the incision. This protective hydroxide double-layer (LDH) comprises MgAl-LDH and ZnAl-LDH, wherein the numbers of Mg atom and Al atom in the former molecule is 6 and 2, respectively, and the number of Al atom in the latter molecule is 2. In terms of stability, the stability of ZnAl-LDH is more than 5 times that of MgAl-LDH, so generally it is the formation of ZnAl-LDH hydroxide double-layer that protects the coating and incision and improves the corrosion resistance. When the total amount of ZnAl-LDH is 5 times that of MgAl-LDH, the total content of Al in the hydroxide double-layer is 2 times that of Mg. Therefore, the content of Al in the coating is at least 2 times that of Mg. However, if there are too many aluminum ions in the coating, excess $\text{Al}(\text{OH})_4^-$ compound will be easily precipitated in the early stage, which prevents the formation of a dense hydroxide double-layer. In some embodiments of the present disclosure, the content of aluminum in the coating is preferably 2.3 times the content of magnesium, so that the oxidation of magnesium can be significantly inhibited.

[0031] In some embodiments of the present disclosure, the reason why the thickness of the coating may not be less than 5% of the thickness of the steel sheet is that: if the thickness of the coating is less than 5% of the thickness of the steel sheet, the protective compound double-layer cannot cover sides of the incision of the steel sheet and thus is also impossible to protect the incision of the steel sheet.

[0032] In some embodiments of the present disclosure, the mass fraction of chemical components in the coating may be: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities, wherein the content of aluminum in mass fraction may be 2 to 3 times the content of magnesium and the thickness of the coating may be not less than 5% of the thickness of the steel sheet, which together facilitate the formation of the liquid film containing magnesium ion, aluminum ion and zinc ion with good fluidity on the coating in the early stage of atmospheric corrosion and are beneficial for the liquid film to fully cover the steel sheet at the incision position and to form a dense double-layer of hydroxide compound, thereby obtaining the hot-dipped zinc-aluminum-magnesium coated steel sheet with excellent incision corrosion resistance.

[0033] In some embodiments of the present disclosure, the thickness of the steel sheet may range from 0.5 mm to 6 mm. In the case of relying on the zinc-aluminum-magnesium coating to protect the incision of the steel sheet, there are certain requirements for the thickness of the steel sheet. If the steel sheet is too thick, excellent incision corrosion resistance cannot be achieved. The thickness should generally not exceed 6 mm. If the steel sheet is too thin, there is also a certain risk for application, since the too-thin incision will form extremely sharp corners and pits from the microscopic point of view. The radius of curvature at these locations is often less than the minimum radius of curvature that can be wetted by the surface tension of an aqueous solution. Therefore, they cannot be covered with the solution containing aluminum ions and magnesium ions, so that a protective layer cannot be formed. In some embodiments of the present disclosure, the thickness of the steel sheet is required to be no less than 0.5 mm.

[0034] The applicant has found through research that the thicker the steel sheet, the higher the content of aluminum and magnesium required to achieve better incision corrosion resistance. Specifically: when the thickness of the steel sheet is no more than 2 mm, having the magnesium content being 1% and the aluminum content being 2% in the coating can provide a good incision protection effect, of course, the premise is that the manufacturing requirements of the present disclosure are met. However, as the thickness of the steel sheet increases, lower limits of the required aluminum content and the required magnesium content increase accordingly. Generally, when the thickness of the steel sheet reaches 4 mm, the magnesium content in the coating should not be less than 1.5% and the aluminum content in the coating should not be less than 3%; when the thickness of the steel sheet reaches 5 mm, the magnesium content in the coating should not be less than 2% and the aluminum content in the coating should not be less than 4%; and when the thickness of the steel sheet reaches 6 mm, the magnesium content in the coating should not be less than 3% and the aluminum content in the coating should not be less than 6%.

[0035] The applicant further found through research that adding a certain amount of Ca element to the coating can inhibit the formation of large particles of Mg-Zn compounds on the surface, prevent the premature reaction of aluminum and hydroxide to form precipitation, and improve the fluidity of aluminum ions, so that magnesium ions and aluminum ions are able to more adequately cover the incision site. Therefore, adding a certain amount of Ca element to the coating can improve the corrosion resistance of the incision. In some embodiments of the present disclosure, the addition amount

of Ca element may exceed 0.01%, and the Mg-Zn compound formed therefrom changes from polygonal particles to blunt round particles, and the particle size can be further reduced from 50 microns to no more than 20 microns. If the addition of Ca element exceeds 0.1%, it is easy to cause zinc dross defects in production and produce galvanic corrosion, thereby reducing the corrosion resistance of the coating. In some embodiments of the present disclosure, the addition amount of calcium element may be 0.01% to 0.1%, and it should also satisfy: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; the content of aluminum in mass fraction may be 2 to 3 times that of magnesium; and the thickness of the coating may be not less than 5% of that of the steel sheet.

[0036] In some embodiments of the present disclosure, in the case of adding 0.01% Ca, when the thickness of the steel sheet does not exceed 2.5 mm, the magnesium content in the coating can be 1%, and the aluminum content in the coating can be 2%, such that the coating can provide good incision protection effect. In some embodiments of the present disclosure, when the thickness of the steel sheet reaches 4 mm, the magnesium content in the coating should not be less than 1.2% and the aluminum content in the coating should not be less than 2.5%; when the thickness of the steel sheet reaches 5 mm, the magnesium content in the coating should not be less than 1.8% and the aluminum content in the coating should not be less than 3.8%; and when the thickness of the steel sheet reaches 6 mm, the magnesium content in the coating should not be less than 2.5% and the aluminum content in the coating should not be less than 5%.

[0037] The present disclosure further provides a manufacture method of a hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance, which may include: obtaining a coating solution by using chemical components of a coating of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance; heating the coating solution to obtain a preheated coating solution with a temperature of the preheated coating solution being controlled to be not lower than a melting point of the coating solution and not higher than 500°C; obtaining a steel sheet, and immersing the steel sheet in the preheated coating solution to obtain a coated steel sheet; and cooling the coated steel sheet to obtain the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance.

[0038] In some embodiments of the present disclosure, the temperature of the preheated coating solution may be controlled to be not lower than the melting point of the coating solution and not higher than 500°C. The reason is: if the temperature of the preheated coating solution is too high, the oxidation reaction in the coating bath is violent and the alloying elements on the surface of the coating bath are easily oxidized and evaporated, so that the distribution of the alloying elements in the coating bath is uneven. There are few elements in the surface layer but more elements in the inner layer. Such a nonuniform distribution of the elements in the coating will greatly deteriorate the corrosion resistance of the coating. In some embodiments of the present disclosure, the temperature of the preheated coating solution cannot exceed 500°C. On the other hand, if the temperature of the preheated coating solution is lower than the melting point of the coating solution, the coating solution will solidify.

[0039] In some embodiments of the present disclosure, the obtained steel sheet may have a surface roughness Ra of $1\ \mu\text{m} \sim 2\ \mu\text{m}$. The rough surface morphology of the steel sheet is conducive to improving the adhesion between the coating and the steel sheet, improving the corrosion resistance of the coating during the corrosion process, and making the coating not easily peeled off. But if the surface of the steel sheet is too rough, the following adverse effects will occur: parts of the coating will be significantly thinned and the corrosion resistance of the coating will decrease; the rough ridge on the steel sheet will react rapidly during hot-dipping, forming an excessively thick Fe-Al-Zn compound layer, which consumes aluminum in the coating solution, so that the corrosion resistance of the coating will decrease due to insufficient aluminum in the local area of the coating. Therefore, in some embodiments of the present disclosure, the surface roughness Ra of the obtained steel sheet may be limited to not more than $2.0\ \mu\text{m}$ and not less than $1.0\ \mu\text{m}$.

[0040] In some embodiments of the present disclosure, the steel sheet may be preheated to a steel sheet preheating temperature before the immersion of the steel sheet in the coating solution for bathing, and the steel sheet preheating temperature is controlled according to the thickness of the steel sheet, specifically including: when $0.5\ \text{mm} \leq$ the thickness of the steel sheet $\leq 2\ \text{mm}$, the temperature of the preheated coating solution $\leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution + 10°C; when $2\ \text{mm} <$ the thickness of the steel sheet $\leq 4\ \text{mm}$, the temperature of the preheated coating solution - 5°C $\leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution; and when $4\ \text{mm} <$ the thickness of the steel sheet $\leq 6\ \text{mm}$, the temperature of the preheated coating solution - 10°C $\leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution - 5°C.

[0041] In some embodiments of the present disclosure, when $0.5\ \text{mm} \leq$ the thickness of the steel sheet $\leq 2\ \text{mm}$, before hot-dipping, the steel sheet preheating temperature may range from the temperature of the preheated coating solution to a temperature 10°C higher than the temperature of the preheated coating solution (i.e., the temperature of the preheated coating solution $\leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution + 10°C). This is to ensure the formation of a stable Fe-Al-Zn compound between the steel sheet and the coating solution, improve the adhesion of the coating, and make the coating not easily peeled off. However, if the temperature is too high, the compound will be too thick, resulting in loss of corrosion resistance due to the reduction of aluminum in the coating. If the thickness of the steel sheet exceeds 2 mm, during the reaction between the steel sheet and the coating solution, the temperature inside the steel sheet cannot be lowered in time and thus the heat cannot be conducted out in time.

When the temperature of the steel sheet is too high, the heat inside the steel sheet will continue to flow to the outside of the surface of the steel sheet, making the Fe-Al-Zn compound layer formed between the steel sheet and the coating solution too thick, which consumes the aluminum in the coating solution instead, resulting in the loss of corrosion resistance due to the reduction of aluminum in the coating layer. Therefore, in some embodiments of the present disclosure, when the thickness of the steel sheet exceeds 2 mm but does not exceed 4 mm, the steel sheet preheating temperature may range from a temperature 5°C lower than the temperature of the preheated coating solution to the temperature of the preheated coating solution (i.e., the temperature of preheated coating solution - 5°C ≤ the steel sheet preheating temperature ≤ the temperature of the preheated coating solution); and in some embodiments of the present disclosure, when the thickness of the steel sheet exceeds 4 mm but does not exceed 6 mm, the steel sheet preheating temperature may range from a temperature 10°C lower than the temperature of the preheated coating solution to a temperature 5°C lower than the temperature of the preheated solution (i.e., the temperature of the preheated coating solution - 10°C ≤ the steel sheet preheating temperature ≤ the temperature of the preheated coating solution - 5°C).

[0042] In some embodiments of the present disclosure, the cooling the coated steel sheet may include: blowing air or spraying water on a surface of the coating of the coated steel sheet for cooling.

[0043] In some embodiments of the present disclosure, the cooling may include a two-stage cooling, specifically: when the temperature of the coated steel sheet is between the temperature of the coating bath and 360°C, cooling may be performed at a first cooling rate and the first cooling rate may be controlled at: $0 < \text{the first cooling rate} \leq 1^\circ\text{C/s}$; when the temperature of the coated steel sheet is between 360°C and 300°C, cooling may be performed at a second cooling rate and the second cooling rate may be $> 5^\circ\text{C/s}$. The inventors found that when the coating begins to solidify, the coating solution and the substrate rapidly react and form an aluminum-rich compound, and at the same time, a large precipitation of aluminum-rich crystals is formed first. If the cooling rate is appropriate, the formation of a large number of dendrites rich in aluminum and magnesium is favored. Such dendrites rich in aluminum and magnesium are difficult to react with media in subsequent corrosion process and thus have good corrosion resistance. The inventors have also found that when the temperature of the coating is lowered to below 360°C, all the crystals that precipitate first have been all precipitated, and a eutectic reaction process begins. During the eutectic reaction, a mixture structure containing one or more of Al/Zn/Mg-Zn, Al/Mg-Zn or Zn/Mg-Zn is formed. The mixture structure is in different phases and is fine and dense. In subsequent use, such fine and dense mixture structure can quickly react with carbon dioxide and water in the air to form an aqueous solution containing zinc, aluminum and magnesium, which can cover and protect the incision. Therefore, in some embodiments of the present disclosure, in order to form a large amount of dendrites rich in aluminum and magnesium, when the temperature of the coated steel sheet is between the temperature of the coating bath and 360°C, cooling may be performed at the first cooling rate and the first cooling rate may be controlled at: $0 < \text{the first cooling rate} \leq 1^\circ\text{C/s}$. In some embodiments of the present disclosure, in order to promote the formation of a fine and dense eutectic structure (a mixture structure containing one or more of Al/Zn/Mg-Zn, Al/Mg-Zn or Zn/Mg-Zn) on the surface of the coating, when the temperature of the coated steel sheet is between 360°C and 300°C, cooling may be performed at the second cooling rate and the second cooling rate may be $\geq 5^\circ\text{C/s}$.

[0044] One or more technical solutions of the embodiments of the present disclosure are beneficial for the steel sheet forming the liquid film containing magnesium ion, aluminum ion and zinc ion with good fluidity on the surface in the early stage of atmospheric corrosion, such that the liquid film can fully cover the steel sheet at the incision position and a dense double-layer of hydroxide compound is formed, thereby obtaining a hot-dipped zinc-aluminum-magnesium coated steel sheet with excellent incision corrosion resistance.

[0045] A hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance and manufacturing method therefor of the present disclosure are described in detail below in combination with experimental data. A hot-rolled steel sheet was used as the substrate, and the material of the hot-rolled steel sheet was CQ grade.

[0046] Test groups 1-17 were established according to one or more technical solutions of the embodiments of the present disclosure. In addition, comparison groups 1-12 were established. Among them, the test groups 1-6 and the comparison groups 1-6 use cold-rolled steel sheet as the substrate, and the material of the steel sheet was CQ grade. The test groups 7-17 and the comparison groups 7-12 use the hot-rolled steel sheet as the substrate, and the material of the steel sheet was CQ grade. In the test groups 1-17 and the comparative groups 1-12, the coated steel sheet was prepared according to the relevant steps in the manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance provided by the present disclosure. The difference among the test groups 1-17 and the comparison groups 1-12 was the chemical compositions of the coating solutions as shown in Table 1. Specific manufacturing processes and parameters are shown in Table 2.

EP 4 163 411 A1

Table 1

Group	Al content in coating	Mg content in coating	Ca content in coating	Al content/Mg content in coating	Thickness of coating	Thickness of steel sheet	Thickness of coating/Thickness of steel sheet
	wt%	wt%	wt%		micro	mm	
Test group 1	2	1	0	2.0	5	0.5	1.00%
Test group 2	2.5	1	0	2.5	7	1	0.70%
Test group 3	3	1.5	0	2.0	10	1.5	0.67%
Test group 4	4	1.5	0.1	2.7	20	2.5	0.80%
Test group 5	3.8	1.5	0.01	2.5	20	3	0.67%
Test group 6	2.5	1.0	0.05	2.5	15	2.8	0.54%
Test group 7	6	3	0	2.0	30	6	0.50%
Test group 8	4.5	2	0	2.3	30	5	0.60%
Test group 9	8	3.5	0	2.3	40	4	1.00%
Test group 10	11	4	0	2.8	20	4	0.50%
Test group 11	12	4	0	3.0	30	5	0.60%
Test group 12	9	3.2	0.05	2.8	30	6	0.50%
Test group 13	2.4	1	0.01	2.4	30	3	1.00%
Test group 14	2.5	1.2	0.02	2.1	30	4	0.75%
Test group 15	3.8	1.5	0.05	2.5	30	5	0.60%
Test group 16	6	2	0.02	3.0	30	5	0.60%
Test group 17	5	2.5	0.08	2.0	30	6	0.50%
Comparison group 1	1.2	1	0	1.2	8	1	0.80%
Comparison group 2	3	0.5	0	6.0	10	1.2	0.83%
Comparison group 3	3	2	0	1.5	7	1.2	0.58%
Comparison group 4	4	2	0.2	2.0	5	2	0.25%
Comparison group 5	5	3	0	1.7	4	0.25	1.60%
Comparison group 6	2	2	0	1.0	10	2.5	0.40%
Comparison group 7	3	5	0	0.6	8	4	0.20%

EP 4 163 411 A1

(continued)

Group	Al content in coating	Mg content in coating	Ca content in coating	Al content/Mg content in coating	Thickness of coating	Thickness of steel sheet	Thickness of coating/Thickness of steel sheet
	wt%	wt%	wt%		micro	mm	
Comparison group 8	15	6	0.2	2.5	20	5	0.40%
Comparison group 9	13	2	0.01	6.5	7	5	0.14%
Comparison group 10	4	2	0	2.0	40	6	0.67%
Comparison group 11	6	3	0	2.0	40	8	0.50%
Comparison group 12	8	2	0	4.0	30	8	0.38%

Table 2

Group	Temperature of preheated coating solution	Temperature of preheated steel sheet	Roughness of steel sheet	First cooling rate	Second cooling rate
	°C	°C	micro	°C/s	°C/s
Test group 1	420	420	1	0.5	10
Test group 2	440	440	1.2	0.1	12
Test group 3	430	430	1.3	0.4	12
Test group 4	450	445	1.5	0.2	10
Test group 5	500	495	1.9	0.8	5
Test group 6	410	408	2	1	8
Test group 7	440	430	2	0.1	10
Test group 8	450	445	1.2	0.2	12
Test group 9	490	487	1.9	0.9	12
Test group 10	500	496	1.9	0.3	10
Test group 11	400	390	1	0.9	5
Test group 12	400	393	2	0.9	8
Test group 13	450	445	1.3	0.1	12
Test group 14	430	420	1.2	0.2	5
Test group 15	430	420	1.8	0.2	11
Test group 16	450	440	1.9	0.8	10

(continued)

Group	Temperature of preheated coating solution	Temperature of preheated steel sheet	Roughness of steel sheet	First cooling rate	Second cooling rate
	°C	°C	micro	°C/s	°C/s
Test group 17	450	440	2	0.03	8
Comparison group 1	460	460	0.8	1.2	3
Comparison group 2	470	480	0.8	0.3	8
Comparison group 3	430	450	1.2	3	10
Comparison group 4	510	510	1.2	0.4	12
Comparison group 5	520	500	1.5	0.8	12
Comparison group 6	430	440	2.1	0.2	2
Comparison group 7	500	460	2.3	0.2	12
Comparison group 8	550	500	4.3	5	9
Comparison group 9	590	500	2.1	5	3
Comparison group 10	450	450	2.9	0.2	12
Comparison group 11	430	450	1.2	0.8	12
Comparison group 12	470	460	1.9	0.2	2

[0047] The incision corrosion resistance was evaluated for the zinc-aluminum-magnesium coated steel sheets obtained from the above test groups 1-17 and comparative groups 1-12. A neutral salt spray testing was used for evaluation for 480 hours and the area ratio of red rust at the incision position was observed. Using a bending method, the zinc-aluminum-magnesium-coated steel sheets obtained from the test groups 1-17 and the comparison groups 1-12 were respectively bent by 90° and then the proportion of peeling of the coating was observed. The experimental evaluation results are shown in Table 3.

Table 3

Group	Area ratio of red rust (%)	Proportion of peeling of coating (%)
Test group 1	1	0
Test group 2	3	0
Test group 3	2	0
Test group 4	0	0
Test group 5	0	0
Test group 6	0	0

(continued)

Group	Area ratio of red rust (%)	Proportion of peeling of coating (%)
Test group 7	1	0
Test group 8	3	0
Test group 9	2	0
Test group 10	2	0
Test group 11	2	0
Test group 12	0	0
Test group 13	0	0
Test group 14	0	0
Test group 15	0	0
Test group 16	0	0
Test group 17	0	0
Comparison group 1	12	2
Comparison group 2	17	2
Comparison group 3	15	0
Comparison group 4	10	0
Comparison group 5	18	0
Comparison group 6	20	4
Comparison group 7	14	5
Comparison group 8	20	10
Comparison group 9	21	10
Comparison group 10	20	0
Comparison group 11	34	0
Comparison group 12	23	0

[0048] As can be seen from Table 3, as for the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance obtained in the test groups 1-17, the area ratios of red rust were in the range of 0 ~ 3%; and the proportions of peeling of the coating were all 0%. As for the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance obtained in the comparative groups 1-12, the area ratios of red rust were in the range of 12% ~ 34%; and the proportions of peeling of the coating were 2% ~ 10%. Obviously, the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance obtained according to the test groups 1-17 of the embodiments of the present disclosure showed a significant lower percentage of red rust area and peeling in coating.

[0049] In the comparison groups 1-12, the incision corrosion resistance was poor since the coating did not satisfy the following requirements: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; the content of aluminum in mass fraction is 2 to 3 times the content of magnesium; and the thickness of the resulted coating is not less than 5‰ of the thickness of the steel sheet.

[0050] To sum up, the manufacturing method of the hot-dipped zinc-aluminum-magnesium coating with incision corrosion resistance provided by the present disclosure is beneficial for the steel sheet forming the liquid film containing magnesium ion, aluminum ion and zinc ion with good fluidity on the surface in the early stage of atmospheric corrosion, such that the liquid film can fully cover the steel sheet at the incision position and a dense double-layer of hydroxide compound is formed, thereby obtaining the hot-dipped zinc-aluminum-magnesium coated steel sheet with excellent incision corrosion resistance.

[0051] Finally, it should also be noted that the terms "comprise", "include" or any other variation thereof are intended to encompass a non-exclusive inclusion, such that a process, method, article or device comprising a series of elements includes not only those elements, but also other elements not expressly listed or inherent to such a process, method,

article or device.

[0052] Although the preferred embodiments of the present disclosure have been described, additional changes and modifications to these embodiments may occur to those skilled in the art once the basic inventive concepts are known. Therefore, the appended claims are intended to be construed to include the preferred embodiment and all changes and modifications that fall within the scope of the present disclosure.

[0053] It will be apparent to those skilled in the art that various changes and modifications can be made to the present disclosure without departing from the spirit and scope of the present disclosure. Thus, the present disclosure is also intended to cover such modifications and variations provided that such modifications and variations of the present disclosure fall within the scope of the claims of the present disclosure and their equivalents.

Claims

1. A hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance, comprising a steel sheet and a coating,
characterized in that,

mass fractions of chemical components in the coating are: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and rest being zinc and inevitable impurities; and the mass fraction of aluminum is 2 to 3 times the mass fraction of magnesium; and
a thickness of the coating is not less than 5% of a thickness of the steel sheet.

2. The hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 1, **characterized in that,** the thickness of the steel sheet ranges from 0.5 mm to 6 mm.

3. The hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 1 or 2, **characterized in that,** the mass fractions of magnesium and aluminum in the coating are controlled based on the thickness of the steel sheet, comprising:

when $0.5 \text{ mm} \leq \text{the thickness of the steel sheet} \leq 2 \text{ mm}$, the mass fractions of the chemical components in the coating are: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $2 \text{ mm} < \text{the thickness of the steel sheet} \leq 4 \text{ mm}$, the mass fractions of the chemical components in the coating are: 3% ~ 12% for aluminum, 1.5% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $4 \text{ mm} < \text{the thickness of the steel sheet} \leq 5 \text{ mm}$, the mass fractions of the chemical components in the coating are: 4% ~ 12% of aluminum, 2% ~ 4% of magnesium, and the rest being zinc and inevitable impurities; and when $5 \text{ mm} < \text{the thickness of the steel sheet} \leq 6 \text{ mm}$, the mass fractions of the chemical components in the coating are: 6% ~ 12% for aluminum, 3% ~ 4% for magnesium, and the rest being zinc and inevitable impurities.

4. The hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 1, **characterized in that,** the mass fractions of the chemical components in the coating are: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, 0.01% ~ 0.1% for calcium, and the rest being zinc and inevitable impurities; the mass fraction of aluminum is 2 to 3 times the mass fraction of magnesium; and the thickness of the coating is not less than 5% of the thickness of the steel sheet.

5. The hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 4, **characterized in that,** when the mass fraction of calcium is 0.01%, the mass fractions of magnesium and aluminum in the coating are controlled based on the thickness of the steel sheet, comprising:

when $0.5 \text{ mm} \leq \text{the thickness of the steel sheet} \leq 2.5 \text{ mm}$, the mass fractions of chemical components in the coating are: 2% ~ 12% for aluminum, 1% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $2.5 \text{ mm} < \text{the thickness of the steel sheet} \leq 4 \text{ mm}$, the mass fractions of the chemical components in the coating are: 2.5% ~ 12% for aluminum, 1.2% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; when $4 \text{ mm} < \text{the thickness of the steel sheet} \leq 5 \text{ mm}$, the mass fractions of the chemical components in the coating are: 3.8% ~ 12% for aluminum, 1.8% ~ 4% for magnesium, and the rest being zinc and inevitable impurities; and when $5 \text{ mm} < \text{the thickness of the steel sheet} \leq 6 \text{ mm}$, the mass fractions of the chemical components in the coating are: 5% ~ 12% for aluminum, 2.5% ~ 4% for magnesium, and the rest being zinc and inevitable impurities.

6. A manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to any one of claims 1-5, **characterized by** comprising:

obtaining a coating solution by using the chemical components of the coating of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance of any one of claims 1-5;
 heating the coating solution to obtain a preheated coating solution with a temperature of the preheated coating solution being controlled to be not lower than a melting point of the coating solution and not higher than 500°C;
 obtaining a steel sheet, and immersing the steel sheet in the preheated coating solution to obtain a coated steel sheet; and
 cooling the coated steel sheet to obtain the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance.

7. The manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 6, **characterized in that**, the cooling the coated steel sheet comprises:

when a temperature of the coated steel sheet is between a temperature of the coating bath and 360°C, the cooling is performed at a first cooling rate and the first cooling rate is controlled at: $0 < \text{the first cooling rate} \leq 1^\circ\text{C/s}$; and
 when the temperature of the coated steel sheet is between 360°C and 300°C, the cooling is performed at a second cooling rate and the second cooling rate is $\geq 5^\circ\text{C/s}$.

8. The manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 6, **characterized in that**, the steel sheet is preheated to a steel sheet preheating temperature before the immersion of the steel sheet in the coating solution for bathing, and a range of the steel sheet preheating temperature is the temperature of the preheated coating solution $\pm 10^\circ\text{C}$.

9. The manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 6, **characterized in that**, the steel sheet is preheated to a steel sheet preheating temperature before the immersion of the steel sheet in the coating solution for bathing, and the steel sheet preheating temperature is controlled based on the thickness of the steel sheet, comprising:

when $0.5 \text{ mm} \leq \text{the thickness of the steel sheet} \leq 2 \text{ mm}$, the temperature of the preheated coating solution $\leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution $+ 10^\circ\text{C}$;
 when $2 \text{ mm} < \text{the thickness of the steel sheet} \leq 4 \text{ mm}$, the temperature of the preheated coating solution $- 5^\circ\text{C} \leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution; and
 when $4 \text{ mm} < \text{the thickness of the steel sheet} \leq 6 \text{ mm}$, the temperature of the preheated coating solution $- 10^\circ\text{C} \leq$ the steel sheet preheating temperature $\leq$ the temperature of the preheated coating solution $- 5^\circ\text{C}$.

10. The manufacturing method of the hot-dipped zinc-aluminum-magnesium coated steel sheet with incision corrosion resistance according to claim 6, **characterized in that**, the obtaining the steel sheet comprises obtaining the steel sheet with a surface roughness Ra of $1 \mu\text{m} \sim 2 \mu\text{m}$.

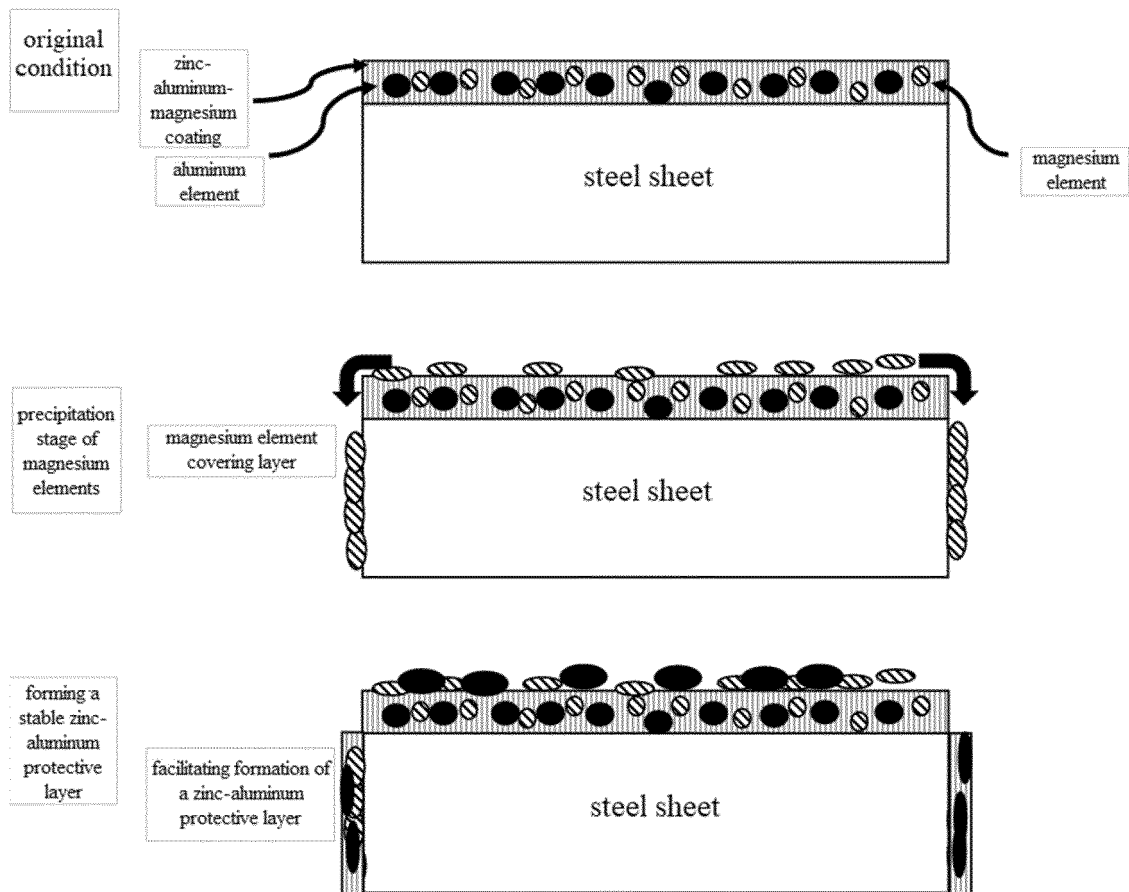


FIG. 1

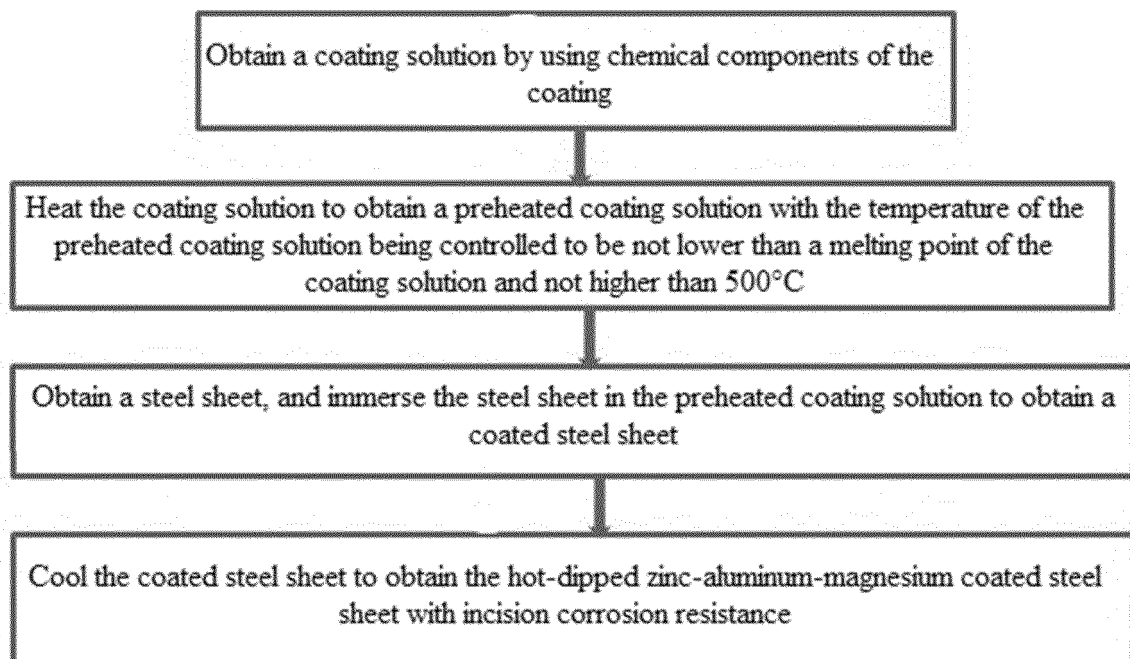


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/121167

A. CLASSIFICATION OF SUBJECT MATTER

C23C 2/06(2006.01)i; C23C 2/26(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS; CNTXT; VEN; WOTXT; EPTXT; USTXT; CNKI; ELSEVIER SCIENCE; PATENTICS; : 首钢, 锌-铝-镁, 锌镁铝, 铝, 镁, 热浸镀, 热镀, 钢板, 镀层, 厚度, 附着量, 预热, 加热, 冷却, calcium, Zn-Al-Mg, magnesium, galvanized, Ca, steel, Mg, Al, hot-dip, aluminum, preheat, cool+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	TW 201114946 A1 (NIPPON STEEL CORPORATION) 01 May 2011 (2011-05-01) claims 1, 3, 7, embodiment 1	1-10
X	CN 1398304 A (NISSHIN STEEL CO., LTD.) 19 February 2003 (2003-02-19) description page 6 paragraph 6 - page 7 paragraph 2, embodiment 1(A5)	1-10
X	CN 110983224 A (SHOUGANG GROUP CO., LTD.) 10 April 2020 (2020-04-10) description, paragraphs 69-77, embodiments 10-18	1-3, 6-10
Y	CN 110983224 A (SHOUGANG GROUP CO., LTD.) 10 April 2020 (2020-04-10) description, paragraphs 69-77, embodiments 10-18	4-10
X	CN 110004389 A (SHOUGANG GROUP CO., LTD.) 12 July 2019 (2019-07-12) description, paragraphs 31-59	1-3, 6-10
Y	CN 110004389 A (SHOUGANG GROUP CO., LTD.) 12 July 2019 (2019-07-12) description, paragraphs 31-59	4-10

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

05 January 2021

Date of mailing of the international search report

03 February 2021

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2020/121167

C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 110835757 A (SHOUGANG GROUP CO., LTD.) 25 February 2020 (2020-02-25) description paragraphs 5, 10, 36	4-10

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2020/121167

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