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(71) Applicant: **POSCO Co., Ltd**
Gyeongsangbuk-do 37859 (KR)

(72) Inventors:
• **LEE, Jae-Hoon**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **SEONG, Hwan-Goo**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **KIM, Jae-Joong**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **NA, Hyun-Taek**
Gwangyang-si, Jeollanam-do 57807 (KR)

(74) Representative: **Meissner Bolte Partnerschaft**
mbB
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

(54) **STEEL SHEET AND METHOD FOR MANUFACTURING SAME**

(57) The present invention relates to a steel sheet
suitable for various uses including use in automobile

parts and, more specifically, to a steel sheet and a
method for manufacturing same.

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Description

Technical Field

- 5 **[0001]** The present disclosure relates to a steel sheet suitable for various applications including automobile parts, and more particularly, to a steel sheet and a method for manufacturing the same.

Background Art

- 10 **[0002]** To address the global climate crisis, automobile manufacturers are demanding that steelmakers supply automotive steel sheets with progressively reduced CO₂ emissions, with the goal of achieving carbon neutrality by 2050. For this reason, steelmakers have recently been developing automotive steel sheets with reduced CO₂ emissions through the recycling of steel scrap, using existing blast furnace-converter steelmaking methods or electric arc furnace steelmaking methods.
- 15 **[0003]** When steel scrap is used as a raw material, it is difficult to remove tramp elements such as Cu and Ni contained in the steel scrap during refining, and they become included in the steel after refining. These tramp elements cause problems such as deteriorating the physical properties of the steel or degrading the surface quality. Therefore, until now, high-grade thin sheet products, represented by automotive steel sheets, have been manufactured using hot metal as the main raw material and a method that extremely controls the content of tramp elements
- 20 while significantly reducing C and N in the steel in the general blast furnace-converter process.
- [0004]** Meanwhile, a technology for manufacturing automotive steel sheets with excellent formability from electric furnace steel containing tramp elements using an electric arc furnace steelmaking method has been proposed as follows.
- 25 **[0005]** Patent Documents 1 and 2 disclose a technology for manufacturing cold-rolled steel sheets with excellent formability. Specifically, these documents disclose a cold-rolled steel sheet that has excellent cold formability despite containing a large amount of tramp elements. However, these technologies do not consider the objective of improving the poor plating adhesion of the steel sheet, nor the means to achieve that objective.
- [0006]** As described above, although technologies for manufacturing automotive steel sheets containing tramp elements have been proposed, an automotive steel sheet with both improved formability and plating adhesion despite
- 30 containing tramp elements has not yet been developed.
- [0007]** (Patent Document 1) Japanese Application Publication No. 1995-118795
- [0008]** (Patent Document 2) Japanese Application Publication No. 1998-025541

Disclosure of Invention

- 35
- ### Technical Problem
- [0009]** An aspect of the present disclosure is to provide a steel sheet with improved formability and plating adhesion despite containing tramp elements in the manufacturing of automotive steel sheets by recycling steel scrap, and a
- 40 method for manufacturing the same.
- [0010]** The problems of the present disclosure are not limited to the above-mentioned content. A person of ordinary skill in the art to which the present disclosure pertains will have no difficulty in understanding additional problems of the present disclosure from the overall description of the present specification.

Solution to Problem

- [0011]** According to an aspect of the present disclosure, a steel sheet is provided, comprising, by weight %, carbon (C): more than 0% to 0.0700%, silicon (Si): more than 0% to 0.800%, manganese (Mn): more than 0% to 1.000%, aluminum (Al): more than 0% to 0.500%, phosphorus (P): 0 to 0.080%, sulfur (S): 0 to 0.0500%, nitrogen (N): 0 to 0.0300%, nickel (Ni): more than 0% to 1.000%, chromium (Cr): more than 0% to 1.000%, molybdenum (Mo): more than 0% to 1.000%, tin (Sn): more than 0% to 0.5000%, and one or more selected from the following groups (i) to (vi), with the remainder being Fe and other unavoidable impurities.
- 50
- (i) Copper (Cu): 0 to 1.000%
- 55 (ii) One or more of titanium (Ti): 0 to 0.500%, niobium (Nb): 0 to 0.500%, vanadium (V): 0 to 0.500%, and boron (B): 0 to 0.0200%
- (iii) One or more of magnesium (Mg): 0 to 0.050%, calcium (Ca): 0 to 0.050%, and rare earth elements (REM) excluding yttrium (Y): 0 to 0.050%

- (iv) One or more of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%
- (v) One or more of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%
- (vi) One or more of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%

[0012] In an embodiment of the present disclosure, when the average content (wt%) of (Cr+Ni+Mo+Sn) in the surface layer region is A, and the average content (wt%) of (Cr+Ni+Mo+Sn) in the central region is B, a steel sheet satisfying $A/B = 0.15$ to 30.00 may be provided.

[0013] In an embodiment of the present disclosure, a steel sheet in which the microstructure is a single phase of ferrite may be provided, and the average grain size of the ferrite may be 6 to $50\ \mu\text{m}$.

[0014] In an embodiment of the present disclosure, a steel sheet may be provided in which the value (I/II) obtained by dividing the average grain size (I) of the cold-rolled steel sheet by the average grain size (II) of the hot-rolled steel sheet satisfies 0.60 to 0.95 .

[0015] This steel sheet of the present disclosure has high strength and excellent formability, and when it undergoes a subsequent plating process, it may also have excellent plating adhesion.

[0016] In an embodiment of the present disclosure, the steel sheet may have a product of tensile strength (TS) and elongation (EI) ($TS \times EI$) of 4.0 to $30.0\ \text{GPa}\cdot\%$, and a product of the Lankford value (r-value) and elongation ($r\text{-value} \times EI$) of 20 to 200% .

[0017] In an embodiment of the present disclosure, the steel sheet may include a plating layer formed on at least one surface thereof, and the plating layer may have a powdering peeling width of less than $7\ \text{mm}$.

[0018] According to another aspect of the present disclosure, a method for manufacturing a steel sheet is provided, comprising the steps of: preparing a steel slab; heating the steel slab in a temperature range of 900 to 1300°C ; finish rolling the heated steel slab in an austenite region at or above the Ar_3 transformation point or in a ferrite region at or below the Ar_3 transformation point to obtain a hot-rolled steel sheet; coiling the hot-rolled steel sheet at 700°C or higher; cooling the coiled hot-rolled steel sheet to a temperature range of 250 to 350°C at a rate of $10.0^\circ\text{C}/\text{min}$ or less; cold rolling the cooled hot-rolled steel sheet with a cold reduction ratio of 50% or more to obtain a cold-rolled steel sheet; and annealing the cold-rolled steel sheet at 600°C or higher for 10 seconds or longer.

[0019] In an embodiment of the present disclosure, the steel slab may have the alloy composition described above.

[0020] In an embodiment of the present disclosure, the steel slab may be obtained by continuously casting molten steel obtained through a steelmaking process in an electric arc furnace.

[0021] In an embodiment of the present disclosure, the annealing step may be performed by heating the cold-rolled steel sheet obtained by cold rolling to an annealing temperature at a heating rate of 2 to $60^\circ\text{C}/\text{s}$.

[0022] In an embodiment of the present disclosure, the method may further include a step of plating the cold-rolled steel sheet after the annealing treatment, and the plating treatment may be hot-dip plating or electroplating.

[0023] In an embodiment of the present disclosure, the hot-dip plating may be hot-dip galvanizing in a temperature range of 440 to 520°C , and after the hot-dip galvanizing, an alloying heat treatment may be additionally performed.

[0024] According to yet another aspect of the present disclosure, there is provided a steel sheet manufactured by the manufacturing method described above, wherein the value obtained by dividing the average grain size (I) of the cold-rolled steel sheet after the annealing treatment by the average grain size (II) of the hot-rolled steel sheet may satisfy 0.60 to 0.95 .

Advantageous Effects of Invention

[0025] According to the present disclosure, it is possible to provide an automotive steel sheet with improved formability and plating adhesion despite containing tramp elements.

[0026] Since the steel sheet of the present disclosure is manufactured by recycling steel scrap, it has an excellent advantage in CO_2 reduction effect when applied as a material for automobile bodies and the like.

[0027] The various and beneficial advantages and effects of the present disclosure are not limited to the above-mentioned contents, and will be more easily understood in the process of describing specific embodiments of the present disclosure.

Best Mode for the Invention

[0028] The technical terms used herein are only for the purpose of describing specific embodiments and are not intended to limit the present disclosure. The singular forms used herein include the plural forms as well, unless the context clearly indicates otherwise.

[0029] The meaning of "comprising" as used in the specification specifies a particular characteristic, region, integer, step, operation, element, and/or component, and does not exclude the presence or addition of other particular characteristics, regions, integers, steps, operations, elements, components, and/or groups.

[0030] Unless otherwise defined, all terms, including technical and scientific terms, used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Terms defined in commonly used dictionaries should be further interpreted as having a meaning consistent with the relevant technical literature and the present disclosure, and should not be interpreted in an idealized or overly formal sense unless so defined.

[0031] Hereinafter, a steel sheet according to an aspect of the present disclosure, particularly a steel sheet with excellent formability and plating adhesion, will be described in detail. It should be noted that unless otherwise specified, when indicating the content of each element in the present disclosure, it means % by weight. In addition, the ratio of crystals or structures is based on area unless otherwise specified.

[0032] Hereinafter, in the description of the steel sheet, unless otherwise specified, it is clarified that it means a cold-rolled steel sheet.

Mode for the Invention

[0033] A steel sheet according to an aspect of the present disclosure may include, by weight %, carbon (C): more than 0% to 0.0700%, silicon (Si): more than 0% to 0.800%, manganese (Mn): more than 0% to 1.000%, aluminum (Al): more than 0% to 0.500%, phosphorus (P): 0 to 0.080%, sulfur (S): 0 to 0.0500%, nitrogen (N): 0 to 0.0300%, nickel (Ni): more than 0% to 1.000%, chromium (Cr): more than 0% to 1.000%, molybdenum (Mo): more than 0% to 1.000%, and tin (Sn): more than 0% to 0.5000%.

[0034] Hereinafter, the reasons for limiting the alloy composition of the steel sheet provided in the present disclosure as described above will be explained in detail.

Carbon (C): more than 0% to 0.0700%

[0035] Carbon (C) is an effective element for securing the strength of steel.

[0036] In an embodiment of the present disclosure, if the content of C exceeds 0.0700%, it is difficult to secure the desired elongation and r-value. Therefore, the C may be contained at 0.0700% or less. In another embodiment of the present disclosure, the C may be 0.0650% or less, or 0.0600% or less.

[0037] Meanwhile, C is an essential element in steel manufacturing, and its content is more than 0%. However, in an embodiment of the present disclosure, if the content is less than 0.0003%, the effect of reducing C may hardly be obtained, and rather, it is undesirable because it causes an increase in steelmaking costs. Therefore, the C may be included at 0.0003% or more. In another embodiment of the present disclosure, the C may be included at 0.0010% or more, or 0.0015% or more.

Silicon (Si): more than 0% to 0.800%

[0038] Silicon (Si) is an element that has a strength-improving effect through solid solution strengthening, and is useful for improving formability by strengthening ferrite and homogenizing the structure. In addition, Si is a necessary element for deoxidation during steelmaking.

[0039] In an embodiment of the present disclosure, if the content of Si exceeds 0.800%, it causes plating defects such as non-plating during plating, and there is a problem of impairing the weldability of the steel sheet. Accordingly, the Si may be contained at 0.800% or less. In another embodiment of the present disclosure, the Si may be 0.700% or less.

[0040] Meanwhile, in an embodiment of the present disclosure, Si may be included in an amount exceeding 0%, and considering the manufacturing cost, its content may be 0.001% or more.

Manganese (Mn): more than 0% to 1.000%

[0041] Manganese (Mn) is a useful element for simultaneously improving the strength and ductility of steel.

[0042] In an embodiment of the present disclosure, if the content of Mn exceeds 1.000%, formability is deteriorated, which is undesirable. In another embodiment of the present disclosure, the Mn may be 0.900% or less, or 0.400% or less.

[0043] Meanwhile, in an embodiment of the present disclosure, Mn may be included in an amount exceeding 0%, and considering the manufacturing cost, its content may be 0.001% or more.

Aluminum (Al): more than 0% to 0.500%

[0044] Aluminum (Al) is an element that acts as a deoxidizer by combining with oxygen (O) in steel. In addition,

similar to Si, it is an element that strengthens ferrite, homogenizes the structure, and improves formability.

[0045] In an embodiment of the present disclosure, if the content of Al exceeds 0.500%, there is a problem that formability is rather deteriorated. Therefore, the Al may be included at 0.500% or less. In another embodiment of the present disclosure, the Al may be contained at 0.400% or less.

[0046] Meanwhile, in an embodiment of the present disclosure, Al may be included in an amount exceeding 0%. However, since controlling the content of Al to less than 0.001% causes a problem of increased manufacturing costs, considering this, its content may be 0.001% or more.

Phosphorus (P): 0.080% or less

[0047] Phosphorus (P) is an element added to improve the strength of steel. In an embodiment of the present disclosure, if the content of P exceeds 0.080%, it impairs the formability of the steel and causes a problem of inducing brittleness. Accordingly, the P may be included at 0.080% or less. According to another embodiment of the present disclosure, the P may be included at 0.070% or less.

[0048] Meanwhile, in an embodiment of the present disclosure, P may be 0%, but considering the manufacturing cost, its content may be limited to 0.001% or more.

Sulfur (S): 0.0500% or less

[0049] Sulfur (S) is an element unavoidably added during the steel manufacturing process and impairs the ductility of the steel by forming MnS inclusions through combination with Mn in the steel. Accordingly, in an embodiment of the present disclosure, the content of S may be limited to 0.0500% or less. In another embodiment of the present disclosure, S may be included at 0.0400% or less.

[0050] Meanwhile, in an embodiment of the present disclosure, S may be 0%, but since it may be unavoidably contained in the steel, its content may exceed 0%. In an embodiment of the present disclosure, controlling the content of S to less than 0.0010% causes a problem of a significant increase in manufacturing costs. Accordingly, S may be contained at 0.0010% or more.

Nitrogen (N): 0.0300% or less

[0051] Nitrogen (N) is an element unavoidably added during the steel manufacturing process and is an element that causes cracks in the slab by forming nitrides during the continuous casting process. Accordingly, in an embodiment of the present disclosure, N may be included at 0.0300% or less.

[0052] Meanwhile, in an embodiment of the present disclosure, N may be 0%, but since it may be unavoidably contained in the steel, its content may exceed 0%. In an embodiment of the present disclosure, controlling the content of N to less than 0.0010% causes a problem of a significant increase in manufacturing costs. Accordingly, N may be contained at 0.0010% or more.

Nickel (Ni): more than 0% to 1.000%

[0053] Nickel (Ni) is an element that stabilizes austenite and suppresses corrosion. In addition, Ni is a useful element for suppressing hydrogen-delayed fracture by enriching on the surface of the steel sheet and preventing the intrusion of hydrogen moving into the steel interior.

[0054] In an embodiment of the present disclosure, if the content of Ni is excessive, the formability becomes poor, and as an expensive element, there is a concern that the manufacturing cost will increase. Accordingly, their contents can be limited to 1.000% or less, respectively. In another embodiment of the present disclosure, the Ni may be included at 0.900% or less.

[0055] Meanwhile, in an embodiment of the present disclosure, Ni may be included in an amount exceeding 0%, and in order to sufficiently obtain the effect of Ni, it may be contained at 0.001% or more.

Chromium (Cr): more than 0% to 1.000%

[0056] Chromium (Cr) is an element that suppresses the decomposition of austenite and stabilizes austenite during the alloying treatment of the manufactured steel sheet.

[0057] In an embodiment of the present disclosure, if the content of Cr is excessive, the formability is deteriorated. Therefore, considering this, it may be limited to 1.000% or less. In another embodiment of the present disclosure, the Cr may be included at 0.900% or less.

[0058] Meanwhile, in an embodiment of the present disclosure, Cr may be included in an amount exceeding 0%,

and in order to sufficiently obtain the effect of Cr, it may be contained at 0.001% or more.

Molybdenum (Mo): more than 0% to 1.000%

5 **[0059]** Molybdenum (Mo), similar to the aforementioned Cr, is an element that suppresses the decomposition of austenite and stabilizes austenite during the alloying treatment of the manufactured steel sheet.

[0060] In an embodiment of the present disclosure, if the content of Mo is excessive, the formability is deteriorated. Therefore, considering this, it may be limited to 1.000% or less. According to another embodiment of the present disclosure, the Mo may be included at 0.900% or less.

10 **[0061]** Meanwhile, in an embodiment of the present disclosure, Mo may be included in an amount exceeding 0%, and in order to sufficiently obtain the effect of Mo, it may be contained at 0.001% or more.

Tin (Sn): more than 0% to 0.5000%

15 **[0062]** Tin (Sn) is an element that improves the plating wettability and plating adhesion of steel. In an embodiment of the present disclosure, if the content of tin in the steel exceeds 0.5000%, the brittleness of the steel increases, causing a problem of cracking during hot or cold working. According to another embodiment of the present disclosure, the Sn may be included at 0.4000% or less.

[0063] Meanwhile, in an embodiment of the present disclosure, Sn may be included in an amount exceeding 0%, and in order to sufficiently obtain the effect of Sn, it may be included at 0.0005% or more.

20 **[0064]** The steel sheet of the present disclosure may further include one or more selected from the following groups (i) to (vi) in addition to the above-mentioned alloy composition. It is clarified that the following elements can all be added selectively, and therefore, their content includes 0%. Meanwhile, the elements of groups (i) to (vi) may be referred to as tramp elements.

- 25
- (i) Copper (Cu): 0 to 1.000%
 - (ii) One or more of titanium (Ti): 0 to 0.500%, niobium (Nb): 0 to 0.500%, vanadium (V): 0 to 0.500%, and boron (B): 0 to 0.0200%
 - (iii) Magnesium (Mg): 0 to 0.050%, calcium (Ca): 0 to 0.050%, and rare earth elements (REM) excluding yttrium (Y): 0 to 0.050%
 - 30 (iv) One or more of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%
 - (v) One or more of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%
 - (vi) One or more of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%

35 (i) Copper (Cu): 0 to 1.000%

[0065] Copper (Cu) is an element that stabilizes austenite and suppresses corrosion. In addition, Cu is a useful element for suppressing hydrogen-delayed fracture by enriching on the surface of the steel sheet and preventing the intrusion of hydrogen moving into the steel interior.

40 **[0066]** In an embodiment of the present disclosure, if the content of Cu is excessive, the formability becomes poor, so its content may be limited to 1.000% or less. In another embodiment of the present disclosure, the Cu may be included at 0.900% or less.

[0067] Meanwhile, in an embodiment of the present disclosure, since there is no problem in achieving the object of the present disclosure even if Cu is not intentionally added, its content may include 0%. However, when Cu is added, 45 in order to obtain the above-mentioned effect, it may be included at 0.001% or more.

(ii) One or more of titanium (Ti): 0 to 0.500%, niobium (Nb): 0 to 0.500%, vanadium (V): 0 to 0.500%, and boron (B): 0 to 0.0200%

50 **[0068]** Titanium (Ti), niobium (Nb), and vanadium (V) are elements that form precipitates in steel, and the formation of these precipitates can improve the strength and impact toughness of the steel. In particular, Ti, Nb, and V can prevent the deterioration of formability due to solute C and solute N by precipitating solute C and solute N in the steel as carbides, nitrides, and the like.

[0069] In an embodiment of the present disclosure, when these elements are additionally added, they may be added 55 at 0.001% or more, respectively, and the above-mentioned effects may be obtained therefrom. However, if the content of each exceeds 0.500%, the addition effect is saturated and there is a problem of increased manufacturing costs, so the upper limit of each element may be limited to 0.500%. According to another embodiment of the present disclosure, when these elements are added, they may be included at 0.400% or less, respectively.

[0070] Boron (B) is an element that improves the hardenability of steel to increase its strength and suppresses the nucleation of grain boundaries.

[0071] In an embodiment of the present disclosure, if the content of B exceeds 0.0200%, the deep drawability of the steel may be deteriorated. Therefore, when B is added, its content may be limited to 0.0200% or less. According to another embodiment, the B may be included at 0.0100% or less. Meanwhile, in an embodiment of the present disclosure, when B is additionally added, in order to obtain its effect, it may be included at 0.0001% or more. According to another embodiment, when B is added, it may be included at 0.0005% or more or 0.0010% or more.

(iii) Magnesium (Mg): 0 to 0.050%, calcium (Ca): 0 to 0.050%, and rare earth elements (REM) excluding yttrium (Y): 0 to 0.050%

[0072] Magnesium (Mg), calcium (Ca), and rare earth elements (REM) excluding yttrium (Y) are elements that improve the ductility of steel by spheroidizing sulfides in the steel. In an embodiment of the present disclosure, when the above-mentioned elements are added, if the content of each element exceeds 0.050%, the above-mentioned effect is saturated and the manufacturing cost increases, so their contents may be limited to 0.050% or less, respectively.

[0073] Generally, rare earth elements (REM) refer to a total of 17 metal elements such as scandium (Sc), yttrium (Y), lanthanum (La), cerium (Ce), and the like. According to an embodiment of the present disclosure, since the content of yttrium (Y) is separately limited below, it is clarified that in an embodiment of the present disclosure, REM refers to the 16 elements excluding Y.

(iv) One or more of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%

[0074] Tungsten (W) and zirconium (Zr) are elements that improve the hardenability of steel to increase its strength. In an embodiment of the present disclosure, if W and Zr are present in excess, the above-mentioned effect is saturated and the manufacturing cost increases. Accordingly, when W and Zr are added, their contents may be limited to 0.50% or less, respectively.

(v) One or more of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%

[0075] Antimony (Sb) and cobalt (Co) are elements that improve the plating wettability and plating adhesion of steel. In an embodiment of the present disclosure, when these elements are added, if their content exceeds 0.5000% respectively, the brittleness of the steel increases, causing a problem of cracking during hot or cold working. Therefore, the content of each element may be limited to 0.5000% or less. According to another embodiment of the present disclosure, when these elements are added, they can be included at 0.4000% or less, respectively. Meanwhile, in order to sufficiently obtain the desired effect by adding these elements, they may be included at 0.0005% or more, respectively.

(vi) One or more of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%

[0076] Yttrium (Y) and hafnium (Hf) are elements that improve the corrosion resistance of steel. In an embodiment of the present disclosure, when these elements are added, if their content exceeds 0.200% respectively, the ductility of the steel may be deteriorated, so the content of each element may be limited to 0.200% or less.

[0077] In an embodiment of the present disclosure, the steel sheet may include the remaining Fe and other unavoidable impurities in addition to the above-mentioned components. However, in a normal manufacturing process, unintended impurities may be unavoidably mixed in from raw materials or the surrounding environment, so they cannot be completely excluded. Since these impurities are known to anyone of ordinary skill in the art, all of their contents are not specifically mentioned in this specification. In addition, the additional addition of effective components other than the above-mentioned components is not completely excluded.

[0078] According to an embodiment of the present disclosure, the content of some tramp elements contained at a specific point based on the thickness direction of the steel sheet may be controlled as follows, and from this, the improvement of the plating adhesion of the steel sheet can be promoted.

[0079] Specifically, in an embodiment of the present disclosure, when the average content (wt%) of (Cr+Ni+Mo+Sn) in the surface layer region of the steel sheet is A, and the average content (wt%) of (Cr+Ni+Mo+Sn) in the central region of the steel sheet is B, A/B may satisfy 0.15 to 30.00.

[0080] In an embodiment of the present disclosure, A/B is significant in that it is used as an index indicating the plating adhesion of the steel sheet. If the value of A/B is less than 0.15 or exceeds 30.00, there is a problem that specific tramp elements contained in the steel are not uniformly distributed.

[0081] Here, the central region refers to the $t/2$ point in the thickness direction. In addition, the surface layer region refers to the region from the surface to the inflection point, which is the point where the concentration changes (or changes abruptly) when the concentration gradient of Cr, Ni, Mo, and Sn is measured in the thickness direction.

[0082] In an embodiment of the present disclosure, the inflection point refers to the point corresponding to 99% of the (Cr+Ni+Mo+Sn) content of the central region in the concentration gradient measurement value when the (Cr+Ni+Mo+Sn) content of the outermost surface is greater than the (Cr+Ni+Mo+Sn) content of the central region, and refers to the point corresponding to 1% of the (Cr+Ni+Mo+Sn) content of the central region in the concentration gradient measurement value when the (Cr+Ni+Mo+Sn) content of the outermost surface is smaller than the (Cr+Ni+Mo+Sn) content of the central region. As a non-limiting example, the concentration of the above-mentioned elements may be measured using FE-SEM or a glow discharge spectrometer (GDS).

[0083] As one example, when measuring the concentration of (Cr+Ni+Mo+Sn) in the thickness direction of the steel sheet, the (Cr+Ni+Mo+Sn) content of the outermost surface has the highest value, and the value may tend to decrease linearly from the outermost surface to the central region.

[0084] As another example, when measuring the concentration of (Cr+Ni+Mo+Sn) in the thickness direction of the steel sheet, the (Cr+Ni+Mo+Sn) content of the outermost surface has the lowest value, and the value may tend to increase linearly from the outermost surface to the central region.

[0085] Meanwhile, it is well known in the technical field of the present disclosure that a steel sheet, that is, a cold-rolled steel sheet, is obtained through a series of rolling processes. That is, as will be described in detail later, the cold-rolled steel sheet according to the present disclosure is obtained through a cold rolling process (and a subsequent annealing heat treatment process) on a hot-rolled steel sheet obtained through a hot rolling and coiling process.

[0086] With respect to such a hot-rolled steel sheet and a cold-rolled steel sheet, in an embodiment of the present disclosure, it is preferable that the ratio of the average grain size of the hot-rolled steel sheet to the average grain size of the cold-rolled steel sheet obtained by cold rolling and annealing the hot-rolled steel sheet satisfies the following.

[0087] Specifically, in an embodiment of the present disclosure, the value (I/II) obtained by dividing the average grain size (I) of the cold-rolled steel sheet by the average grain size (II) of the hot-rolled steel sheet may satisfy 0.60 to 0.95.

[0088] As described above, according to the present disclosure, by controlling the grain size of the hot-rolled steel sheet obtained by hot rolling, the grain size of the cold-rolled steel sheet obtained by subsequent cold rolling and annealing heat treatment may be secured, and thereby, strength and formability may be excellently obtained.

[0089] If the value of I/II is less than 0.60, there is a problem that the rigidity increases significantly due to the excessively fine grains of the hot-rolled steel sheet, whereas if the value exceeds 0.95, the grains become coarse, making it impossible to secure strength and formability.

[0090] In an embodiment of the present disclosure, the microstructure of the steel sheet may be a single phase of ferrite.

[0091] That is, if the microstructure of the steel sheet includes a structure other than ferrite, such as pearlite, or bainite or martensite formed at a low temperature, the intended formability cannot be secured. However, it is not intended to exclude even a very small amount of impurity structure that is unavoidably included in the process, and it is naturally included in the scope of the present disclosure.

[0092] In an embodiment of the present disclosure, the average grain size of the ferrite may be 6 to 50 μm . If the average grain size of the ferrite is less than 6 μm , the rigidity of the steel may increase and become brittle, whereas if the size exceeds 50 μm , it may be disadvantageous for securing strength by grain refinement.

[0093] Meanwhile, it is clarified that the grain sizes of the hot-rolled steel sheet and the cold-rolled steel sheet mentioned above mean the grain size of ferrite.

[0094] The steel sheet according to an embodiment of the present disclosure has not only high strength but also excellent formability.

[0095] Specifically, according to an embodiment of the present disclosure, the steel sheet may satisfy a product of tensile strength (TS) and elongation (EI) ($\text{TS} \times \text{EI}$) of 4.0 to 30.0 GPa·%, and also a product of Lankford value (r-value) and elongation ($\text{r-value} \times \text{EI}$) of 20 to 200%.

[0096] The steel sheet according to an embodiment of the present disclosure may have a plating layer on at least one surface.

[0097] In an embodiment of the present disclosure, the plating layer may be a zinc-based plating layer, and the zinc-based plating layer is a plating layer containing zinc (Zn) as a main component, and the composition of the plating layer commonly applied in the art may be applied equally. At this time, the zinc-based plating layer may also include an alloyed zinc-based plating layer by alloying treatment.

[0098] As such, a steel sheet having a zinc-based plating layer on at least one surface is a zinc-based plated steel sheet, and may be a hot-dip galvanized steel sheet (GI), a galvanized steel sheet (GA), an electrogalvanized steel sheet (EG), an alloyed electrogalvanized steel sheet, or the like.

[0099] In an embodiment of the present disclosure, the steel sheet on which the zinc-based plating layer is formed

on at least one surface may be the steel sheet according to an embodiment of the present disclosure, and it is clarified that the above description can be applied equally to the steel sheet.

[0100] Meanwhile, the steel sheet (cold-rolled steel sheet) according to an embodiment of the present disclosure may have a concentration gradient of specific elements, for example, tramp elements such as Cr, Ni, Mo, and Sn, in the thickness direction from the surface. When a plating layer (for example, a zinc-based plating layer) is formed on at least one surface of such a cold-rolled steel sheet, the tramp elements may further diffuse into the plating layer due to the influence of the temperature during plating or the temperature during alloying treatment. As a result, the concentration gradient of the tramp elements in the plated steel sheet may be realized in the thickness direction of the base material from the interface between the base material, which is the substrate steel sheet, and the plating layer, but it may also be realized from the alloy layer formed at the interface between the base material and the plating layer.

[0101] That is, the tramp elements may have a concentration gradient represented by A/B due to the difference in the diffusion rate of the tramp elements that diffuse toward the surface of the steel sheet during the manufacturing process of the cold-rolled steel sheet, and this characteristic of the cold-rolled steel sheet also appears in the plated steel sheet.

[0102] The plated steel sheet according to an embodiment of the present disclosure has an excellent powdering property of the plating layer. Specifically, it may have a feature that the powdering peeling width of the plating layer is less than 7 mm.

[0103] Hereinafter, a method for manufacturing a steel sheet (cold-rolled steel sheet) and a plated steel sheet according to another aspect of the present disclosure will be described in detail.

[0104] First, the steel sheet according to the present disclosure, that is, a cold-rolled steel sheet, may be obtained through a series of processes, for example, [heating of steel slab - hot rolling - coiling - cooling - cold rolling - annealing]. Each process step will be described in detail below, and it is clarified that the following manufacturing process corresponds to one example for manufacturing the cold-rolled steel sheet and the subsequent plated steel sheet of the present disclosure.

[0105] According to an embodiment of the present disclosure, a steel slab or ingot may be manufactured through an electric arc furnace or a new blast furnace-converter process, and the raw materials used in the electric arc furnace or blast furnace-converter process are pig iron along with steel scrap. Here, pig iron means hot metal obtained from a blast furnace-converter process, its cold material (Corrugate), or HBI (Hot Briquetted Iron), etc.

[0106] In the case of an electric arc furnace, desulfurization treatment may be performed by ladle refining after tapping from the electric arc furnace, and desulfurization and vacuum degassing treatment in the subsequent process may be performed. In addition, the steel obtained from the electric arc furnace may be adjusted to have the final desired alloy composition by adding alloy components while performing degassing treatment. Here, as the vacuum degassing treatment method, the RH method and the DH method are common, but oxygen injection into the degassing vessel may be performed concurrently. For oxygen injection, there is an oxygen injection method using a top lance.

[Heating of Steel Slab]

[0107] After preparing a steel slab, it may be heated. At this time, the steel slab may be an ingot. In an embodiment of the present disclosure, the steel slab may have the alloy composition described above, and therefore, the description of the alloy composition of the steel slab is replaced with the above-mentioned content.

[0108] In an embodiment of the present disclosure, the heating temperature when heating the prepared steel slab or ingot may be in the range of 900 to 1300°C. If the heating temperature exceeds 1300°C, there is a possibility that the steel will reach its melting point and melt, whereas if the temperature is less than 900°C, the rolling load during subsequent hot rolling increases, which may deteriorate the stability of hot rolling. In another embodiment of the present disclosure, the heating may be performed at 1160°C or less.

[Hot Rolling]

[0109] The heated steel slab or ingot may be hot-rolled to obtain a hot-rolled steel sheet.

[0110] In an embodiment of the present disclosure, the finishing temperature during hot rolling may be either in the austenite region at or above the Ar₃ transformation point or in the ferrite region at or below the Ar₃ transformation point. However, if the finishing temperature is too low, the rolling load during hot rolling increases, so the lower limit temperature may be limited to 750°C or higher.

[Coiling]

[0111] The hot-rolled steel sheet obtained by hot rolling may be coiled into a coil shape.

[0112] In an embodiment of the present disclosure, the coiling process may be performed at a temperature of 700°C or higher. If the coiling temperature is less than 700°C, the desired grain size of the hot-rolled steel sheet obtained after coiling cannot be secured. In another embodiment of the present disclosure, the coiling process may be performed at 720°C or higher.

[0113] Meanwhile, the upper limit of the coiling temperature is not particularly limited, but considering that scale may be excessively formed on the surface of the hot-rolled coil, the temperature may be limited to 800°C or less.

[0114] The present disclosure may achieve the relationship between the grains of the hot-rolled steel sheet and the subsequent cold-rolled steel sheet, that is, the range of I/II, by performing coiling at the above-mentioned temperature.

[Cooling]

[0115] The coiled hot-rolled steel sheet may be cooled while being uncoiled.

[0116] In an embodiment of the present disclosure, cooling after coiling may be performed to a temperature range of 250 to 350°C at a cooling rate of 10.0°C/min or less. By cooling at such a relatively slow cooling rate, uniform grains in the microstructure may be secured.

[0117] In an embodiment of the present disclosure, if the cooling rate during cooling exceeds 10.0°C/min, there is a possibility that the grains will become coarse. Meanwhile, the lower limit of the cooling rate during cooling is not particularly limited. However, if the cooling rate is excessively lowered, it may put a strain on the cooling equipment, and the grains may also become coarse, so considering this, it may be limited to 0.2°C/min or more.

[0118] In an embodiment of the present disclosure, if the cooling end temperature during cooling is less than 250°C, the cooling time becomes excessive, which may lead to a decrease in productivity, whereas if the cooling end temperature exceeds 350°C, there is a problem of causing a load during subsequent cold rolling.

[Cold Rolling]

[0119] The cooled uncoiled hot-rolled steel sheet may be cold-rolled to obtain a cold-rolled steel sheet.

[0120] In an embodiment of the present disclosure, cold rolling may be performed with a cold reduction ratio of 50% or more. If the cold reduction ratio is less than 50%, it may be difficult to secure the target thickness, and it may be difficult to correct the shape of the steel sheet. According to an embodiment of the present disclosure, the upper limit of the cold reduction ratio during cold rolling is not particularly limited, but if it is too excessive, a cold rolling load may be caused, so considering this, it can be limited to 95% or less.

[Annealing]

[0121] The manufactured cold-rolled steel sheet may be annealed.

[0122] In an embodiment of the present disclosure, the annealing heat treatment may be performed in a general continuous annealing furnace, and may be performed under the condition of heating the cold-rolled steel sheet to 600°C or higher and then heat-treating for 10 seconds or longer. If the temperature during the annealing heat treatment is less than 600°C or the time is less than 10 seconds, recrystallization may not occur sufficiently during the annealing process, which may lead to the generation of an unrecrystallized structure. In this case, the formability of the steel sheet may be poor.

[0123] According to an embodiment of the present disclosure, the upper limits of the temperature and time during the annealing heat treatment are not particularly limited. However, considering the concern of equipment trouble due to high-temperature annealing and the poor powdering property, 960°C and 15 minutes may be set as the upper limits, respectively.

[0124] Meanwhile, in heating the cold-rolled steel sheet to the temperature for annealing heat treatment, heating may be performed at a constant heating rate. As one example, it may be performed at a heating rate of 2 to 60°C/s. If the heating rate during heating is too slow or excessively fast, the grain characteristics intended in the present disclosure may not be secured.

[0125] The cold-rolled steel sheet manufactured through the series of processes described above may have the strength and formability targeted in the present disclosure.

[0126] In particular, the cold-rolled steel sheet according to an embodiment of the present disclosure may have a product of tensile strength (TS) and elongation (EI) ($TS \times EI$) of 4.0 to 30.0 GPa·%, and a product of Lankford value (r-value) and elongation ($r\text{-value} \times EI$) of 20 to 200%.

[0127] Meanwhile, according to an aspect of the present disclosure, a plated steel sheet may be obtained by plating a steel sheet, that is, a cold-rolled steel sheet. The cold-rolled steel sheet at this time may be a cold-rolled steel sheet manufactured through a series of processes according to an embodiment of the present disclosure. From this, the plated steel sheet may have a plating layer on at least one surface of the above-mentioned cold-rolled steel sheet.

[0128] In an embodiment of the present disclosure, the plating treatment may be a hot-dip plating or electroplating process, and each plating process may be performed under conditions commonly practiced in the art.

[0129] As one example, the hot-dip plating may be performed by immersing the cold-rolled steel sheet, on which the annealing heat treatment has been completed, in a hot-dip galvanizing bath containing zinc as a main component. Since the conditions for the hot-dip galvanizing treatment may be based on normal conditions, they are not specifically limited in this specification. However, as one implementation example, GI hot-dip plating may be performed under normal conditions in a temperature range of 440 to 520°C.

[0130] In addition, according to an embodiment of the present disclosure, a galvanized steel sheet (GA) may be obtained by selectively performing an alloying heat treatment on the plated steel sheet on which the zinc-based plating layer is formed. Since the alloying heat treatment may also be based on normal conditions, it is not specifically limited, but as one example, the alloying heat treatment may be performed in a temperature range of 500 to 560°C.

[0131] Furthermore, as another example, the electroplating may form a zinc-based plating layer on at least one surface of the substrate steel sheet (cold-rolled steel sheet) by placing the substrate steel sheet (cold-rolled steel sheet) on the cathode of a vertical plating cell type electroplating simulator and then circulating a plating solution containing zinc (Zn).

[0132] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the following examples are for explaining the present disclosure through examples, and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and matters reasonably inferred therefrom.

Mode for the Invention

(Example)

[0133] Steel slabs having the alloy compositions of Table 1 below were prepared. The steel slabs were manufactured into hot-rolled steel sheets through a [reheating - hot rolling - coiling - cooling] process according to the respective conditions shown in Table 2 below. Thereafter, cold-rolled steel sheets were obtained by subjecting each hot-rolled steel sheet to a series of subsequent processes (cold rolling - annealing) shown in Table 2 below. At this time, the cooling process after coiling was performed to a temperature range of 250 to 350°C.

[0134] The steel slabs were obtained through the following process. First, molten steel was obtained by charging molten iron from an existing blast furnace and blended steel scrap into an electric arc furnace. Then, this molten steel was transferred to a ladle and subjected to vacuum degassing treatment in an RH degasser (0.1 torr), and at the same time, alloying components were added to produce molten steel having the intended composition. Thereafter, the molten steel was manufactured into a slab by continuous casting.

[0135] The microstructure and mechanical properties of the manufactured steel sheets were measured and evaluated, and all results are shown in Table 3 below. At this time, the phase type of the microstructure and properties were measured/evaluated for the cold-rolled steel sheets, and the grain size was measured for both the hot-rolled steel sheets and the cold-rolled steel sheets. The cold-rolled steel sheet at this time corresponds to the cold-rolled steel sheet after annealing.

[0136] First, the microstructure of each cold-rolled steel sheet was observed using a scanning electron microscope (SEM) after collecting a specimen at t/4 in the thickness direction, polishing it, and then nital etching the cross-section of the polished specimen. After the nital etching, the structure with no irregularities on the specimen surface was identified as ferrite, and the structure with a spherical or lamellar structure was identified as cementite. In addition, to confirm the grain size characteristics of ferrite, the average grain size was measured through an optical microscope for each specimen collected at t/4 in the thickness direction of the hot-rolled steel sheet and the cold-rolled steel sheet and whose cross-section was nital etched.

[0137] In addition, a tensile test was conducted to evaluate the properties of each cold-rolled steel sheet. The tensile test was evaluated with a specimen collected according to the JIS No. 5 standard based on the direction 90 degrees to the rolling direction of the rolled plate, and the product of tensile strength (TS) and elongation (EI) (TS×EI) was calculated. In addition, for the same specimen, the Lankford value (r-value) was measured by a 3-point method after 15% tensile pre-strain, and the average value in the rolling direction (L direction), the direction perpendicular to the rolling direction (C direction), and the 45-degree direction to the rolling direction (D direction) was obtained by the following calculation formula.

$$r\text{-value} = (r_L + 2r_D + r_C) / 4$$

[0138] Meanwhile, in order to confirm the content (wt%) of specific elements (Cr, Ni, Mo, and Sn) at a specific point in the thickness direction of the cold-rolled steel sheet, the cross-section of each specimen was removed by FIB, and

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then measured by component analysis of FE-SEM. At this time, the content in the surface layer region according to the definition of the surface layer region and the central region ($t/2$) in the thickness direction were measured respectively, and after repeated measurement for a total of 30 times at random points, the maximum and minimum values of the analyzed values of each element were removed, and the content was calculated as an average value.

[0139] In addition, for the evaluation of powdering property, a 45-degree V-bending test was performed on the plated steel sheets obtained by plating each cold-rolled steel sheet in a hot-dip galvanizing bath at 440 to 480°C. At this time, the evaluation surface was placed on the inside of the bend, and after bending at 60 degrees using a mold with a tip curvature radius of 1 mm, a tape was attached to the inside and then the tape was removed, and the powdering property was evaluated on a 5-point scale for the plated layer that peeled off with this tape. The specific evaluation criteria were set as follows, and 2 points or more were evaluated as passing.

Peeling width less than 2 mm: 5 points

Peeling width 2 mm or more and less than 3 mm: 4 points

Peeling width 3 mm or more and less than 5 mm: 3 points

Peeling width 5 mm or more and less than 7 mm: 2 points

Peeling width 7 mm or more: 1 point

[Table 1]

Steel Grade	Alloy Composition (wt%)												
	C	Si	Mn	P	S	Al	N	Cr	Ni	Mo	Sn	Ti	Others
A	0.0 008	0.0 04	0.0 55	0.0 03	0.0 016	0.0 23	0.0 013	0.8 10	0.6 50	0.8 20	0.3 30	0.0 14	Hf 0.004
B	0.0 015	0.0 03	0.0 94	0.0 04	0.0 060	0.0 26	0.0 037	0.6 40	0.8 70	0.4 40	0.2 00	0.0 35	Nb 0.056 Y 0.005
C	0.0 027	0.0 14	0.1 63	0.0 12	0.0 070	0.0 31	0.0 054	0.4 80	0.3 70	0.4 70	0.1 10	0.0 53	W 0.02
D	0.0 039	0.0 23	0.2 04	0.0 25	0.0 130	0.0 34	0.0 063	0.3 60	0.2 70	0.3 40	0.0 40	0.0 55	Mg 0.003
E	0.0 156	0.0 26	0.2 53	0.0 37	0.0 160	0.0 36	0.0 088	0.2 90	0.2 20	0.2 30	0.0 50	0.0 76	Cu 0.26 Zr 0.02
F	0.0 283	0.0 27	0.2 92	0.0 48	0.0 220	0.0 35	0.0 096	0.1 60	0.1 30	0.1 30	0.0 10	0.0 96	B 0.0024 Sb 0.002
G	0.0 502	0.0 34	0.3 72	0.0 62	0.0 340	0.0 31	0.0 165	0.0 02	0.0 02	0.0 01	0.0 01	0.1 45	Ca 0.005 REM 0.001
XA	0.0 744	0.0 23	0.2 35	0.0 25	0.0 210	0.0 30	0.0 045	0.1 90	0.2 40	0.1 80	0.0 23	0.0 37	-
XB	0.0 021	0.8 31	0.2 50	0.0 27	0.0 250	0.0 27	0.0 055	0.2 40	0.2 10	0.2 10	0.0 24	0.0 54	-
XC	0.0 022	0.0 23	1.0 68	0.0 18	0.0 330	0.0 32	0.0 063	0.2 10	0.2 50	0.1 60	0.0 22	0.0 55	-
XD	0.0 023	0.0 25	0.2 26	0.0 20	0.0 320	0.5 33	0.0 068	0.2 30	0.1 80	0.1 90	0.0 17	0.0 64	-
XE	0.0 021	0.0 24	0.2 23	0.0 25	0.0 270	0.0 32	0.0 343	0.2 00	0.2 00	0.1 70	0.0 20	0.2 96	-
XF	0.0 024	0.0 28	0.2 09	0.0 24	0.0 230	0.0 35	0.0 057	1.1 10	0.2 20	0.2 40	0.0 22	0.0 51	-
XG	0.0 022	0.0 23	0.3 18	0.0 26	0.0 250	0.0 33	0.0 051	0.2 40	1.0 40	0.2 60	0.0 21	0.0 47	-
XH	0.0 023	0.0 26	0.2 77	0.0 28	0.0 240	0.0 26	0.0 046	0.3 00	0.2 50	1.1 90	0.0 24	0.0 41	-
XI	0.0 021	0.0 24	0.2 40	0.0 24	0.0 230	0.0 28	0.0 045	0.3 20	0.2 40	0.1 60	0.5 21	0.0 39	-
In Table 1, REM means REM excluding Y.													

[Table 2]

Steel Grade	Reheating Temp. (°C)	Finishing Rolling Temp. (°C)	Coiling Temp. (°C)	Cooling after Coiling (°C/min)	Cold Reduction Ratio (%)	Heating Rate (°C/s)	Annealing Temp. (°C)	Annealing Time (s)	I/II	Specimen No.
A	1160	880	750	0.6	76	47	930	40	0.97	1
B	1160	880	750	0.6	76	40	820	40	0.58	2
A	1280	930	820	0.5	76	46	930	600	0.94	3
B	1050	780	400	0.5	76	38	750	20	0.57	4
A	1160	880	750	0.3	76	56	880	40	0.73	5
B	1160	880	750	0.5	76	34	880	40	0.76	6
B	1310	950	750	0.6	76	27	880	40	0.83	7
B	880	620	460	0.6	76	25	880	40	0.77	8
B	1270	950	820	0.8	76	33	880	40	0.62	9
B	1160	880	680	0.7	76	34	880	40	0.89	10
B	1160	880	750	0.8	47	33	880	40	0.53	11
B	1160	880	750	1.1	76	36	570	40	0.36	12
B	1160	880	750	0.9	76	34	970	40	0.97	13
B	1160	880	750	0.8	76	26	880	5	0.35	14
B	1160	880	750	0.8	76	27	880	1000	0.98	15
B	1160	880	700	0.1	76	19	860	40	0.97	16
B	1160	880	700	10.5	76	23	860	40	0.54	17
B	1160	880	700	0.8	76	1	880	40	0.98	18
B	1160	880	750	0.6	76	63	880	40	0.51	19
C	1050	880	750	0.7	76	24	860	40	0.83	20
D	1050	880	750	1.1	76	16	920	40	0.90	21
E	1160	880	720	1.3	76	7	900	40	0.63	22
F	1250	880	780	2.5	76	6	900	40	0.71	23
G	1160	880	780	5.7	76	2	880	40	0.74	24
XA	1160	880	750	1.0	76	16	880	40	0.38	25

(continued)

Steel Grade	Reheating Temp. (°C)	Finishing Rolling Temp. (°C)	Coiling Temp. (°C)	Cooling after Coiling (°C/min)	Cold Reduction Ratio (%)	Heating Rate (°C/s)	Annealing Temp. (°C)	Annealing Time (s)	I/II	Specimen No.
XB	1160	880	750	0.7	76	21	880	40	0.53	26
XC	1160	880	750	0.6	76	24	880	40	0.45	27
XD	1160	880	750	0.8	76	23	880	40	0.43	28
XE	1160	880	750	0.9	76	25	880	40	0.54	29
XF	1160	880	750	0.6	76	27	880	40	0.56	30
XG	1160	880	750	0.5	76	16	880	40	0.52	31
XH	1160	880	750	0.6	76	17	880	40	0.46	32
XI	1160	880	750	0.9	76	23	880	40	0.47	33
In Table 2, I/II means the value (I/II) obtained by dividing the average grain size (I) of the cold-rolled steel sheet by the average grain size (II) of the hot-rolled steel sheet.										

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[Table 3]

	Specimen No.	A/B	Average Grain Size of Cold-Rolled Steel Sheet (μm)	TS×EI (GPa%)	r-value× EI (%)	Powdering Property
5	1	0.51	47	28	194	4
	2	0.50	24	19	90	4
	3	31.24	54	34	211	1
10	4	0.48	5	3.7	18	4
	5	0.16	36	26	199	5
	6	0.37	34	24	158	5
	7	0.38	17	3.8	18	4
15	8	0.50	9	3.5	16	3
	9	32.20	33	22	152	1
	10	0.47	14	3.3	16	3
20	11	0.56	15	5.6	13	3
	12	0.13	8	3.4	14	1
	13	0.39	38	24	181	3
	14	0.12	10	3.5	15	1
25	15	0.27	34	23	158	3
	16	0.44	43	26	175	2
	17	0.38	12	3.4	16	3
30	18	0.43	36	24	139	2
	19	0.35	13	3.6	15	3
	20	0.86	27	27	130	5
	21	2.59	22	18	98	4
35	22	8.55	19	16	59	4
	23	17.2	14	6.9	35	3
	24	29.2	7	4.3	22	3
40	25	16.0	5	2.6	14	2
	26	25.4	9	3.7	16	2
	27	23.8	6	3.5	15	3
	28	20.1	8	2.8	13	3
45	29	21.7	5	2.6	14	3
	30	22.8	11	3.6	17	2
	31	24.3	13	3.4	12	2
50	32	18.5	10	2.9	15	2
	33	16.8	12	2.6	18	2
In Table 3, A/B means the value (A/B) obtained by dividing the average content (wt%, A) of (Cr+Ni+Mo+Sn) in the surface layer region by the average content (wt%, B) of (Cr+Ni+Mo+Sn) in the central region.						

55 **[0140]** As shown in Tables 1 to 3 above, in the case of the specimens that satisfied both the alloy composition and manufacturing conditions proposed in the present disclosure, the microstructure was formed to have the intended grains, and the strength and formability were all excellent.

[0141] On the other hand, in the case of the specimens that deviated from one or more of the alloy composition and

manufacturing conditions of the present disclosure, the grains of the microstructure were not formed as intended, or specific elements were non-uniformly distributed, resulting in poor properties in at least one of strength, formability, and plating adhesion.

[0142] As described above, according to the present invention, that is, by controlling the grain size characteristics and the content ratio of specific elements according to positions in the thickness direction, excellent workability and plating adhesion may be achieved simultaneously, which is technically significant.

Claims

1. A steel sheet, comprising, by weight %:

carbon (C): more than 0% to 0.0700%, silicon (Si): more than 0% to 0.800%, manganese (Mn): more than 0% to 1.000%, aluminum (Al): more than 0% to 0.500%, phosphorus (P): 0 to 0.080%, sulfur (S): 0 to 0.0500%, nitrogen (N): 0 to 0.0300%, nickel (Ni): more than 0% to 1.000%, chromium (Cr): more than 0% to 1.000%, molybdenum (Mo): more than 0% to 1.000%, tin (Sn): more than 0% to 0.5000%, and one or more selected from the following groups (i) to (vi), and a remainder of Fe and other unavoidable impurities,

(i) copper (Cu): 0 to 1.000%,

(ii) one or more of titanium (Ti): 0 to 0.500%, niobium (Nb): 0 to 0.500%, vanadium (V): 0 to 0.500%, and boron (B): 0 to 0.0200%,

(iii) one or more of magnesium (Mg): 0 to 0.050%, calcium (Ca): 0 to 0.050%, and rare earth elements (REM) excluding yttrium (Y): 0 to 0.050%,

(iv) one or more of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%,

(v) one or more of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%, and

(vi) one or more of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%,

wherein, when an average content (wt%) of (Cr+Ni+Mo+Sn) in a surface layer region is A, and an average content (wt%) of (Cr+Ni+Mo+Sn) in a central region is B, A/B satisfies 0.15 to 30.00,

wherein the central region refers to a $t/2$ point in a thickness direction, and the surface layer region refers to a region from a surface to an inflection point, which is a point where a concentration changes when a concentration gradient of Cr, Ni, Mo, and Sn is measured in the thickness direction, wherein the inflection point refers to a point corresponding to 99% of the (Cr+Ni+Mo+Sn) content of the central region in a concentration gradient measurement value when the (Cr+Ni+Mo+Sn) content of an outermost surface is greater than the (Cr+Ni+Mo+Sn) content of the central region, or refers to a point corresponding to 1% of the (Cr+Ni+Mo+Sn) content of the central region in the concentration gradient measurement value when the (Cr+Ni+Mo+Sn) content of the outermost surface is smaller than the (Cr+Ni+Mo+Sn) content of the central region, and wherein the steel sheet has an average grain size of 6 to 50 μm .

2. The steel sheet of claim 1, wherein the steel sheet is a cold-rolled steel sheet manufactured by cold rolling and annealing a hot-rolled steel sheet obtained by hot rolling, and a value (I/II) obtained by dividing an average grain size (I) of the cold-rolled steel sheet by an average grain size (II) of the hot-rolled steel sheet satisfies 0.60 to 0.95.

3. The steel sheet of claim 1, wherein a microstructure of the steel sheet is a single phase of ferrite.

4. The steel sheet of claim 1, wherein a product of tensile strength (TS) and elongation (EI) ($\text{TS} \times \text{EI}$) of the steel sheet is 4 to 30 GPa·%.

5. The steel sheet of claim 1, wherein a product of a Lankford value (r-value) and elongation (EI) ($\text{r-value} \times \text{EI}$) of the steel sheet is 20 to 200%.

6. The steel sheet of claim 1, wherein the steel sheet comprises a plating layer formed on at least one surface thereof.

7. The steel sheet of claim 6, wherein a powdering peeling width of the plating layer is less than 7 mm.

8. A method for manufacturing a steel sheet, the method comprising:

preparing a steel slab comprising, by weight %: carbon (C): more than 0% to 0.0700% or less, silicon (Si): more than 0% to 0.800% or less, manganese (Mn): more than 0% to 1.000% or less, aluminum (Al): more than 0% to 0.500% or less, phosphorus (P): 0 to 0.080%, sulfur (S): 0 to 0.0500%, nitrogen (N): 0 to 0.0300%, nickel (Ni): more than 0% to 1.000% or less, chromium (Cr): more than 0% to 1.000% or less, molybdenum (Mo): more than 0% to 1.000% or less, tin (Sn): more than 0% to 0.5000%, and one or more selected from the following groups (i) to (vi), and a remainder of Fe and other unavoidable impurities;

- (i) copper (Cu): 0 to 1.000%,
- (ii) one or more of titanium (Ti): 0 to 0.500%, niobium (Nb): 0 to 0.500%, vanadium (V): 0 to 0.500%, and boron (B): 0 to 0.0200%,
- (iii) one or more of magnesium (Mg): 0 to 0.050%, calcium (Ca): 0 to 0.050%, and rare earth elements (REM) excluding yttrium (Y): 0 to 0.050%,
- (iv) one or more of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%,
- (v) one or more of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%, and
- (vi) one or more of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%;

heating the steel slab in a temperature range of 900 to 1300°C;
 finish rolling the heated steel slab in an austenite region at or above an Ar₃ transformation point or in a ferrite region at or below the Ar₃ transformation point to obtain a hot-rolled steel sheet;
 coiling the hot-rolled steel sheet at 700°C or higher;
 cooling the coiled hot-rolled steel sheet to a temperature range of 250 to 350°C at a rate of 10.0°C/min or less;
 cold rolling the cooled hot-rolled steel sheet with a cold reduction ratio of 50% or more to obtain a cold-rolled steel sheet; and
 annealing the cold-rolled steel sheet at 600°C or higher for 10 seconds or longer.

9. The method for manufacturing a steel sheet of claim 8, wherein a value (I/II) obtained by dividing an average grain size (I) of the cold-rolled steel sheet after the annealing by an average grain size (II) of the hot-rolled steel sheet after the coiling satisfies 0.60 to 0.95.
10. The method for manufacturing a steel sheet of claim 8, wherein the steel slab is obtained by continuously casting molten steel obtained through a steelmaking process in an electric arc furnace.
11. The method for manufacturing a steel sheet of claim 8, wherein the annealing is performed by heating the cold-rolled steel sheet to an annealing temperature at a heating rate of 2 to 60°C/s.
12. The method for manufacturing a steel sheet of claim 8, further comprising plating the cold-rolled steel sheet after the annealing, wherein the plating is a hot-dip plating or electroplating process.
13. The method for manufacturing a steel sheet of claim 12, wherein the hot-dip plating is hot-dip galvanizing in a temperature range of 440 to 520°C.
14. The method for manufacturing a steel sheet of claim 13, further comprising performing an alloying heat treatment after the hot-dip galvanizing.
15. A steel sheet manufactured by the method for manufacturing a steel sheet of any one of claims 8 to 14, wherein a value obtained by dividing an average grain size (I) of the cold-rolled steel sheet after the annealing by an average grain size (II) of the hot-rolled steel sheet satisfies 0.60 to 0.95.
16. The steel sheet of claim 15, comprising a plating layer formed on at least one surface of the steel sheet.
17. The steel sheet of claim 16, wherein a powdering peeling width of the plating layer is less than 7 mm.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020447

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/44(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/04**(2006.01)i; **C22C 38/02**(2006.01)i; **C22C 38/00**(2006.01)i;
C21D 8/02(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)

C22C 38/44(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/06(2006.01);
C22C 38/14(2006.01)

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

Korean utility models and applications for utility models: IPC as above

Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 강판(steel sheet), 크롬(chromium), 몰리브덴(molybdenum), 니켈(nickel), 구리(copper), 주석(tin), 페라이트(ferrite), 소둔(annealing), 냉각(cooling)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2018-0018804 A (JFE STEEL CORPORATION) 21 February 2018 (2018-02-21) See paragraphs [0046], [0075], [0077] and [0103], claims 1 and 3-5 and table 3.	1-17
A	JP 2004-183057 A (NIPPON STEEL CORP.) 02 July 2004 (2004-07-02) See paragraph [0074] and claims 2 and 4-5.	1-17
A	JP 2015-147968 A (JFE STEEL CORP.) 20 August 2015 (2015-08-20) See paragraph [0048] and claims 1-3.	1-17
A	US 2020-0299798 A1 (JFE STEEL CORPORATION) 24 September 2020 (2020-09-24) See paragraph [0116] and claims 9-10.	1-17
A	JP 2004-143470 A (NIPPON STEEL CORP.) 20 May 2004 (2004-05-20) See paragraph [0032] and claims 1-3.	1-17

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

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

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“E” earlier application or patent but published on or after the international filing date

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search 19 March 2025	Date of mailing of the international search report 19 March 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020447

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REFERENCES CITED IN THE DESCRIPTION

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