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(54) **STEEL SHEET AND MANUFACTURING METHOD THEREOF**

(57) The present invention relates to a steel sheet that is suitable for various uses including in automobile parts and, more specifically, to a steel sheet and a manufacturing method thereof.

EP 4 826 065 A1

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 manufacturing method thereof.

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 by recycling 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 the refining process, and thus they remain 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, as typified by automotive steel sheets, have been manufactured using hot metal as the main raw material and by a method that extremely controls the content of tramp elements while
20 significantly reducing C and N in the steel in a general blast furnace-converter process.

[0004] Meanwhile, a technology for manufacturing an automotive steel sheet 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 a cold-rolled steel sheet with excellent formability. Specifically, they disclose a cold-rolled steel sheet that has excellent cold workability 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.

- 30 **[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 containing tramp elements, has not yet been developed.

(Patent Document 1) Japanese Application Publication No. 1995-118795

(Patent Document 2) Japanese Application Publication No. 1998-025541

- 35 Disclosure of Invention

Technical Problem

- 40 **[0007]** An aspect of the present disclosure is to provide a steel sheet with improved formability and plating adhesion despite containing tramp elements when manufacturing an automotive steel sheet by recycling steel scrap, and a method for manufacturing the same.

- [0008]** The problems of the present disclosure are not limited to the above-mentioned descriptions. A person having 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.

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Solution to Problem

- [0009]** 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%,
50 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%, copper (Cu): more than 0% to 1.000%, nickel (Ni): 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 balance being Fe and other unavoidable impurities.

- 55 (i) Chromium (Cr): 0 to 1.000%
(ii) At least one 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) At least one 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) At least one of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%

(v) At least one of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%

(vi) At least one of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%

[0010] In an embodiment of the present disclosure, a steel sheet may be provided that satisfies $A/B = 0.15$ to 30.00 , where A is the average content (wt%) of (Cu+Ni+Mo+Sn) in a surface layer portion and B is the average content (wt%) of (Cu+Ni+Mo+Sn) in a central portion.

[0011] In an embodiment of the present disclosure, a steel sheet may be provided in which the microstructure is a single phase of ferrite, and the average grain size of the ferrite may be 6 to $50\ \mu\text{m}$.

[0012] 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 a cold-rolled steel sheet by the average grain size (II) of a hot-rolled steel sheet, satisfies 0.60 to 0.95 .

[0013] Such a steel sheet of the present disclosure has high strength and excellent formability, and when subjected to a subsequent plating process, it may also have excellent plating adhesion.

[0014] In an embodiment of the present disclosure, the steel sheet may have a product ($TS \times EI$) of tensile strength (TS) and elongation (EI) of 4.0 to $30.0\ \text{GPa}\cdot\%$, and a product ($r\text{-value} \times EI$) of Lankford value (r-value) and elongation of 20 to 200% .

[0015] In an embodiment of the present disclosure, the steel sheet may include a plating layer on at least one surface, and the plating layer may have a powdering peel-off width of less than $7\ \text{mm}$.

[0016] According to another aspect of the present disclosure, there is provided a method for manufacturing a steel sheet, the method comprising: 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 an 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 at 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.

[0017] In an embodiment of the present disclosure, the steel slab may have the aforementioned alloy composition.

[0018] 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.

[0019] 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 $60^\circ\text{C}/\text{s}$.

[0020] In an embodiment of the present disclosure, the method may further comprise a step of plating the cold-rolled steel sheet after the annealing treatment, wherein the plating treatment may be hot-dip plating or electroplating.

[0021] 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.

[0022] According to yet another aspect of the present disclosure, there is provided a steel sheet manufactured by the aforementioned manufacturing method, 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

[0023] According to the present disclosure, it is possible to provide an automotive steel sheet with improved formability and plating adhesion, despite containing tramp elements.

[0024] The steel sheet of the present disclosure is manufactured by recycling steel scrap, and thus has the advantage of an excellent CO_2 reduction effect when applied as a material for automobile bodies and the like.

[0025] The various and beneficial advantages and effects of the present disclosure are not limited to the above-mentioned descriptions, and will be more easily understood in the course of describing specific embodiments of the present disclosure.

Best Mode for the Invention

[0026] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0027] As used in the specification, the term "comprising" specifies the presence of stated features, regions, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of one or more

other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0028] 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. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0029] 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 when expressing the content of each element in the present disclosure, it means % by weight unless otherwise specified. In addition, the ratio of crystals or structures is based on area unless otherwise specified.

[0030] Hereinafter, in the description of the steel sheet, it is noted that it means a cold-rolled steel sheet unless otherwise specified.

[0031] A steel sheet according to an aspect of the present disclosure may comprise, 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%, copper (Cu): more than 0% to 1.000%, nickel (Ni): more than 0% to 1.000%, molybdenum (Mo): more than 0% to 1.000%, and tin (Sn): more than 0% to 0.5000%.

[0032] Hereinafter, the reason 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%

[0033] Carbon (C) is an effective element for securing the strength of steel.

[0034] 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 in the present disclosure. Therefore, the C content may be 0.0700% or less. In another embodiment of the present disclosure, the C content may be 0.0650% or less, or 0.0600% or less.

[0035] Meanwhile, C is an essential and indispensable 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 not preferable because it causes an increase in steelmaking costs. Therefore, the C content may be 0.0003% or more. In another embodiment of the present disclosure, the C content may be 0.0010% or more, or 0.0015% or more.

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

[0036] Silicon (Si) is an element that has the effect of improving strength through solid solution strengthening, and is useful for strengthening ferrite and homogenizing the structure to improve formability. In addition, Si is an element necessary for deoxidation during steelmaking.

[0037] In an embodiment of the present disclosure, if the Si content exceeds 0.800%, it causes plating defects such as unplated during plating and impairs the weldability of the steel sheet. Accordingly, the Si content may be 0.800% or less. In another embodiment of the present disclosure, the Si content may be 0.700% or less.

[0038] Meanwhile, in an embodiment of the present disclosure, Si may be included in an amount of more than 0%, and considering the manufacturing cost, its content may be 0.001% or more.

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

[0039] Manganese (Mn) is a useful element for simultaneously improving the strength and ductility of steel.

[0040] In an embodiment of the present disclosure, if the Mn content exceeds 1.000%, formability is deteriorated, which is not preferable. In another embodiment of the present disclosure, the Mn content may be 0.900% or less, or 0.400% or less.

[0041] Meanwhile, in an embodiment of the present disclosure, Mn may be included in an amount of more than 0%, and considering the manufacturing cost, its content may be 0.001% or more.

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

[0042] 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.

[0043] In an embodiment of the present disclosure, if the Al content exceeds 0.500%, there is a problem that formability is rather deteriorated. Therefore, the Al content may be 0.500% or less. In another embodiment of the

present disclosure, the Al content may be 0.400% or less.

[0044] Meanwhile, in an embodiment of the present disclosure, Al may be included in an amount of more than 0%. However, since controlling the Al content to less than 0.001% causes a problem of increased manufacturing costs, the content may be limited to 0.001% or more in consideration thereof.

Phosphorus (P): 0.080% or less

[0045] Phosphorus (P) is an element added to improve the strength of steel. In an embodiment of the present disclosure, if the P content exceeds 0.080%, it impairs the formability of the steel and causes embrittlement. Accordingly, the P content may be 0.080% or less. According to another embodiment of the present disclosure, the P content may be 0.070% or less.

[0046] Meanwhile, in an embodiment of the present disclosure, the P content may be 0%, but considering the manufacturing cost, its content may be limited to 0.001% or more.

Sulfur (S): 0.0500% or less

[0047] Sulfur (S) is an element that is unavoidably added during the steel manufacturing process and impairs the ductility of steel by combining with Mn in the steel to form MnS inclusions. Accordingly, in an embodiment of the present disclosure, the S content may be limited to 0.0500% or less. In another embodiment of the present disclosure, the S content may be 0.0400% or less.

[0048] Meanwhile, in an embodiment of the present disclosure, the S content 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 S content to less than 0.0010% causes a problem of a significant increase in manufacturing costs. Accordingly, the S content may be 0.0010% or more.

Nitrogen (N): 0.0300% or less

[0049] Nitrogen (N) is an element that is unavoidably added during the steel manufacturing process and causes cracking of the slab by forming nitrides during the continuous casting process. Accordingly, in an embodiment of the present disclosure, the N content may be 0.0300% or less.

[0050] Meanwhile, in an embodiment of the present disclosure, the N content 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 N content to less than 0.0010% causes a problem of a significant increase in manufacturing costs. Accordingly, the N content may be 0.0010% or more.

Copper (Cu): more than 0% to 1.000%

[0051] Copper (Cu) is an element that stabilizes austenite and suppresses corrosion. In addition, Cu is a useful element for suppressing hydrogen-delayed fracture by being concentrated on the surface of the steel sheet and preventing the invasion of hydrogen moving into the steel.

[0052] In an embodiment of the present disclosure, if the Cu content is excessive, formability becomes poor, so its content may be limited to 1.000% or less. In another embodiment of the present disclosure, the Cu content may be 0.900% or less.

[0053] Meanwhile, in an embodiment of the present disclosure, Cu may be included in an amount of more than 0%, and may be contained in an amount of 0.001% or more in order to sufficiently obtain the effect of Cu.

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

[0054] Nickel (Ni), similar to Cu, is an element that stabilizes austenite and suppresses corrosion. In addition, Ni is a useful element for suppressing hydrogen-delayed fracture by being concentrated on the surface of the steel sheet and preventing the invasion of hydrogen moving into the steel.

[0055] In an embodiment of the present disclosure, if the Ni content is excessive, formability becomes poor, and as an expensive element, there is a concern that the manufacturing cost will increase. Accordingly, its content may be limited to 1.000% or less. In another embodiment of the present disclosure, the Ni content may be 0.900% or less.

[0056] Meanwhile, in an embodiment of the present disclosure, Ni may be included in an amount of more than 0%, and may be contained in an amount of 0.001% or more in order to sufficiently obtain the effect of Ni.

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

[0057] Molybdenum (Mo) is an element that suppresses the decomposition of austenite and stabilizes austenite during the alloying treatment of the manufactured steel sheet.

[0058] In an embodiment of the present disclosure, if the Mo content is excessive, formability is deteriorated, so it may be limited to 1.000% or less in consideration thereof. According to another embodiment of the present disclosure, the Mo content may be 0.900% or less.

[0059] Meanwhile, in an embodiment of the present disclosure, Mo may be included in an amount of more than 0%, and may be contained in an amount of 0.001% or more in order to sufficiently obtain the effect of Mo.

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

[0060] Tin (Sn) is an element that improves the plating wettability and plating adhesion of steel. In an embodiment of the present disclosure, if the tin content in the steel exceeds 0.5000%, the brittleness of the steel increases, causing cracks during hot working or cold working. According to another embodiment of the present disclosure, the Sn content may be 0.4000% or less.

[0061] Meanwhile, in an embodiment of the present disclosure, Sn may be included in an amount of more than 0%, and may be included in an amount of 0.0005% or more in order to sufficiently obtain the effect of Sn.

[0062] The steel sheet of the present disclosure may further include one or more selected from groups (i) to (vi) described below, in addition to the above-mentioned alloy composition. Since all the elements described below may be optionally added, it is noted that their content includes 0%. Meanwhile, the elements of groups (i) to (vi) may be referred to as tramp elements.

(i) Chromium (Cr): 0 to 1.000%

(ii) At least one 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) At least one 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) At least one of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%

(v) At least one of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%

(vi) At least one of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%

(i) Chromium (Cr): 0 to 1.000%

[0063] Chromium (Cr) is an element that suppresses the decomposition of austenite and stabilizes austenite during the alloying treatment of the manufactured steel sheet.

[0064] In an embodiment of the present disclosure, if the Cr content is excessive, formability is deteriorated, so it may be limited to 1.000% or less in consideration thereof. In another embodiment of the present disclosure, the Cr content may be 0.900% or less.

[0065] Meanwhile, in an embodiment of the present disclosure, even if Cr is not intentionally added, there is no problem in achieving the object of the present disclosure, so its content may include 0%. However, in order to obtain the above-mentioned effect when adding Cr, it may be included in an amount of 0.001% or more.

(ii) At least one 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%

[0066] Titanium (Ti), niobium (Nb), and vanadium (V) are elements that form precipitates in steel, and the formation of these precipitates may improve the strength and impact toughness of the steel. In particular, Ti, Nb, and V may 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.

[0067] In an embodiment of the present disclosure, when the elements are additionally added, they may be added in an amount of 0.001% or more, respectively, and the above-mentioned effects can 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, the elements may be included in an amount of 0.400% or less, respectively, when added.

[0068] Boron (B) is an element that improves the hardenability of steel to increase its strength and suppresses nucleation at grain boundaries.

[0069] In an embodiment of the present disclosure, if the B content exceeds 0.0200%, the deep drawability of the

steel may be deteriorated. Therefore, when adding B, its content may be limited to 0.0200% or less. According to another embodiment, the B content may be 0.0100% or less. Meanwhile, in an embodiment of the present disclosure, when B is additionally added, it may be included in an amount of 0.0001% or more in order to obtain its effect. According to another embodiment, when B is added, it may be included in an amount of 0.0005% or more, or 0.0010% or more.

(iii) At least one 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%

[0070] 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, if the content of the aforementioned elements exceeds 0.050% respectively, not only is the above-mentioned effect saturated, but there is also a concern that the manufacturing cost will increase, so their content may be limited to 0.050% or less, respectively.

[0071] In general, rare earth elements (REM) refer to a total of 17 metal elements, including scandium (Sc), yttrium (Y), lanthanum (La), cerium (Ce), or the like. However, according to an embodiment of the present disclosure, the content of yttrium (Y) is separately limited below. Therefore, it is noted that in an embodiment of the present disclosure, REM refers to the 16 elements excluding Y.

(iv) At least one of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%

[0072] Tungsten (W) and zirconium (Zr) are elements that improve the hardenability of steel to increase its strength. According to an embodiment of the present disclosure, if W and Zr are present in excess, not only is the above-mentioned effect saturated, but the manufacturing cost also increases. Accordingly, when adding W and Zr, their content may be limited to 0.50% or less, respectively.

(v) At least one of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%

[0073] Antimony (Sb) and cobalt (Co) are elements that improve the plating wettability and plating adhesion of steel. In an embodiment of the present disclosure, if the content of these elements in the steel exceeds 0.5000% respectively, the brittleness of the steel increases, causing cracks during hot working 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, these elements may be included in an amount of 0.4000% or less, respectively. Meanwhile, in order to sufficiently obtain the desired effect from these elements, they may be included in an amount of 0.0005% or more, respectively.

(vi) At least one of yttrium (Y): 0 to 0.200% and hafnium (Hf): 0 to 0.200%

[0074] Yttrium (Y) and hafnium (Hf) are elements that improve the corrosion resistance of steel. In an embodiment of the present disclosure, if the content of these elements 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.

[0075] In an embodiment of the present disclosure, the steel sheet may include the balance Fe and other unavoidable impurities in addition to the aforementioned components. However, in a normal manufacturing process, unintended impurities from raw materials or the surrounding environment may be unavoidably incorporated, so they cannot be completely excluded. Since these impurities are known to anyone with 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 aforementioned components is not completely excluded.

[0076] 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.

[0077] Specifically, in an embodiment of the present disclosure, when A is the average content (wt%) of (Cu+Ni+Mo+Sn) in the surface layer portion of the steel sheet and B is the average content (wt%) of (Cu+Ni+Mo+Sn) in the central portion of the steel sheet, A/B may satisfy 0.15 to 30.00.

[0078] 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.

[0079] Here, the central portion refers to the t/2 point in the thickness direction. In addition, the surface layer portion refers to the region from the surface to an inflection point, which is a point where the concentration changes (or changes rapidly) when the concentration gradients of Cu, Ni, Mo, and Sn are measured in the thickness direction from

the surface.

[0080] In an embodiment of the present disclosure, when the (Cu+Ni+Mo+Sn) content at the outermost surface is greater than the (Cu+Ni+Mo+Sn) content at the central portion, the inflection point refers to a point corresponding to 99% of the (Cu+Ni+Mo+Sn) content at the central portion in the measured concentration gradient value. When the (Cu+Ni+Mo+Sn) content at the outermost surface is smaller than the (Cu+Ni+Mo+Sn) content at the central portion, it may refer to a point corresponding to 1% of the (Cu+Ni+Mo+Sn) content at the central portion in the measured concentration gradient value. As a non-limiting example, the concentration gradients of the aforementioned elements may be measured using FE-SEM or Glow Discharge Spectrometry (GDS).

[0081] As one example, when measuring the concentration of (Cu+Ni+Mo+Sn) in the thickness direction of the steel sheet, the (Cu+Ni+Mo+Sn) content at the outermost surface has the highest value, and the value may tend to decrease linearly from the outermost surface toward the central portion.

[0082] As another example, when measuring the concentration of (Cu+Ni+Mo+Sn) in the thickness direction of the steel sheet, the (Cu+Ni+Mo+Sn) content at the outermost surface has the lowest value, and the value may tend to increase linearly from the outermost surface toward the central portion.

[0083] 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 by subjecting a hot-rolled steel sheet, which is obtained through hot rolling and coiling processes, to a cold rolling process (and a subsequent annealing heat treatment process).

[0084] 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.

[0085] To be specific, 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.

[0086] As described above, according to the present disclosure, by controlling the grain size of the hot-rolled steel sheet obtained by hot rolling, it is possible to secure the grains of the cold-rolled steel sheet obtained by subsequent cold rolling and annealing heat treatment, and thereby to obtain excellent strength and formability.

[0087] 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. On the other hand, if the value exceeds 0.95, the strength and formability cannot be secured due to the coarsening of the grains.

[0088] In an embodiment of the present disclosure, the microstructure of the steel sheet may be a single phase of ferrite.

[0089] That is, if the microstructure of the steel sheet includes a structure other than ferrite, for example, pearlite, or bainite or martensite formed at a low temperature, the intended formability cannot be secured. However, this is not intended to exclude trace amounts of impurity structures that are unavoidably included in the process, and they are naturally included in the scope of the present disclosure.

[0090] 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 increases and there is a concern that it will become brittle. On the other hand, if the size exceeds 50 μm , there is a concern that it will be disadvantageous for securing strength by grain refinement.

[0091] Meanwhile, it is noted that the grain sizes of the aforementioned hot-rolled steel sheet and cold-rolled steel sheet refer to the grain size of ferrite.

[0092] A steel sheet according to an embodiment of the present disclosure not only has high strength but also has excellent formability.

[0093] Specifically, according to an embodiment of the present disclosure, the steel sheet may satisfy a product (TS $\times$ EI) of tensile strength (TS) and elongation (EI) of 4.0 to 30.0 GPa·%, and also a product (r-value $\times$ EI) of Lankford value (r-value) and elongation of 20 to 200%.

[0094] A steel sheet according to an embodiment of the present disclosure may have a plating layer on at least one surface.

[0095] 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 mainly composed of zinc (Zn), and the composition of the plating layer conventionally applied in the art may be applied equally. At this time, the zinc-based coating layer may also include a zinc-based plating layer alloyed by an alloying treatment.

[0096] As described above, a steel sheet having a zinc-based plating layer on at least one surface is a zinc-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.

[0097] In an embodiment of the present disclosure, the steel sheet on which a zinc-based plating layer is formed on

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

[0098] Meanwhile, a 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 Cu, 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 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. For this reason, the concentration gradient of 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.

[0099] 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.

[0100] A plated steel sheet according to an embodiment of the present disclosure has an excellent powdering property of the plating layer. Specifically, the plating layer may have a characteristic that the powdering peel-off width is less than 7 mm.

[0101] 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.

[0102] First, a steel sheet according to the present disclosure, that is, a cold-rolled steel sheet, may be obtained through a series of processes, for example, [steel slab heating - hot rolling - coiling - cooling - cold rolling - annealing]. Each process step will be described in detail below, and it is noted that the following manufacturing process corresponds to one example for manufacturing the cold-rolled steel sheet of the present disclosure and the subsequent plated steel sheet.

[0103] In 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 refers to hot metal obtained from a blast furnace-converter process, its cold-rolled material (corrugate), or HBI (Hot Briquette Iron), etc.

[0104] 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 of 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, although the RH method and the DH method are common as vacuum degassing treatment methods, oxygen injection into the degassing vessel may be performed concurrently. For oxygen injection, there is an oxygen injection method using a top-blown lance.

[Steel Slab Heating]

[0105] 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 aforementioned alloy composition, and therefore, the description of the alloy composition of the steel slab is replaced by the aforementioned description.

[0106] 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. On the other hand, if the temperature is less than 900°C, the rolling load during subsequent hot rolling may increase, which may deteriorate the hot rolling stability. In another embodiment of the present disclosure, the heating may be performed at 1160°C or less.

[Hot Rolling]

[0107] The heated steel slab or ingot may be hot-rolled to obtain a hot-rolled steel sheet.

[0108] 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, it increases the rolling load during hot rolling, so the lower limit temperature may be limited to 750°C or higher.

[Coiling]

[0109] The hot-rolled steel sheet obtained by the hot rolling may be coiled into a coil shape.

[0110] 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 may not be secured. In another embodiment of the present disclosure, the coiling process may be performed at 720°C or higher.

[0111] Meanwhile, the upper limit of the coiling temperature is not particularly limited, but the temperature may be limited to 800°C or less in consideration of the possibility of excessive scale formation on the surface of the hot-rolled coil.

[0112] By performing coiling at the above-mentioned temperature, the present disclosure can 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.

[Cooling]

[0113] The coiled hot-rolled steel sheet may be cooled while being uncoiled.

[0114] 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 performing cooling at such a relatively slow cooling rate, uniform grains in the microstructure may be secured.

[0115] 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, the cooling equipment may be overloaded, and the grains may also become coarse, so it may be limited to 0.2°C/min or more in consideration thereof.

[0116] In an embodiment of the present disclosure, if the cooling end temperature during cooling is less than 250°C, there is a concern that the cooling time will become excessive and productivity will be reduced. On the other hand, if the cooling end temperature exceeds 350°C, there is a problem of causing a load during subsequent cold rolling.

[Cold Rolling]

[0117] The cooled uncoiled hot-rolled steel sheet may be cold-rolled to obtain a cold-rolled steel sheet.

[0118] In an embodiment of the present disclosure, cold rolling may be performed at 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 it may be limited to 95% or less in consideration thereof.

[Annealing]

[0119] The manufactured cold-rolled steel sheet may be subjected to an annealing heat treatment.

[0120] 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 it 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, there is a concern that un-recrystallized structures may occur because recrystallization does not occur sufficiently during the annealing process. In this case, the formability of the steel sheet may be poor.

[0121] 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, in consideration of the concern of equipment trouble due to high-temperature annealing and the inferiority of powdering properties, the upper limits may be set to 960°C and 15 minutes, respectively.

[0122] 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 the temperature increase is too slow or excessively fast, it may not be possible to secure the grain characteristics intended in the present disclosure.

[0123] The cold-rolled steel sheet manufactured through the aforementioned series of processes may have the strength and formability targeted by the present disclosure.

[0124] In particular, a cold-rolled steel sheet according to an embodiment of the present disclosure may have a product (TS×EI) of tensile strength (TS) and elongation (EI) of 4.0 to 30.0 GPa·%, and a product (r-value×EI) of Lankford value (r-value) and elongation of 20 to 200%.

[0125] 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 aforementioned cold-rolled steel sheet.

[0126] 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 conventionally practiced in the art.

[0127] As one example, the hot-dip plating may be performed by immersing the cold-rolled steel sheet, for which the annealing heat treatment has been completed, in a hot-dip galvanizing bath mainly composed of zinc. Since the conditions for the hot-dip galvanizing treatment may be conventional conditions, they are not specifically limited in this specification. However, as one implementation example, GI hot-dip galvanizing may be performed under conventional conditions in a temperature range of 440 to 520°C.

[0128] 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 a plated steel sheet on which a zinc-based plating layer is formed. The alloying heat treatment may also be performed under conventional conditions and is therefore not particularly limited, but as one example, the alloying heat treatment may be performed in a temperature range of 500 to 560°C.

[0129] Furthermore, as another example, the electroplating may be performed by placing a 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) to form a zinc-based plating layer on at least one surface of the substrate steel sheet (cold-rolled steel sheet).

Mode for the Invention

[0130] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the following examples are for the purpose of illustrating the present disclosure by way of example only, 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.

(Example)

[0131] Steel slabs having the alloy compositions shown in Table 1 below were prepared. Hot-rolled steel sheets were manufactured from the steel slabs through a [reheating - hot rolling - coiling - cooling] process according to the respective conditions shown in Table 2 below. Thereafter, each hot-rolled steel sheet was subjected to a series of subsequent processes (cold rolling - annealing) shown in Table 2 below to obtain a cold-rolled steel sheet. At this time, the cooling process after coiling was performed to a temperature range of 250 to 350°C.

[0132] The steel slab was obtained through the following process. First, molten steel was obtained by charging steel scrap mixed with hot metal from a conventional blast furnace 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, molten steel having the intended composition was manufactured by adding alloy components. Thereafter, the molten steel was manufactured into a slab by continuous casting.

[0133] 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 and physical properties of the microstructure were measured/evaluated for the cold-rolled steel sheet, and the grain size was measured for both the hot-rolled steel sheet and the cold-rolled steel sheet. The cold-rolled steel sheet at this time corresponds to the cold-rolled steel sheet after annealing.

[0134] First, the microstructure of each cold-rolled steel sheet was observed using a scanning electron microscope (SEM) after collecting and polishing a specimen at $t/4$ in the thickness direction, and then etching the cross-section of the polished specimen with nital. 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, in order to confirm the grain size characteristics of ferrite, the average grain size of ferrite 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 etched with nital.

[0135] In addition, a tensile test was conducted to evaluate the physical properties of each cold-rolled steel sheet. The tensile test was evaluated with a test piece collected according to the JIS No. 5 standard based on the direction 90 degrees to the rolling direction of the rolled sheet, and the product ($TS \times EI$) of tensile strength (TS) and elongation (EI) was calculated. In addition, for the same specimen, the Lankford value (r-value) was measured by a three-point method after 15% tensile pre-strain, and the average value of 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:

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

[0136] Meanwhile, in order to confirm the content (wt%) of specific elements (Cu, 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 then measured by component analysis of FE-SEM. At this time, according to the definition of the surface layer portion, the content in the surface layer portion and the central portion ($t/2$) in the thickness direction were measured respectively. After repeating the measurement a total of 30 times at random points, the maximum and minimum values of the analyzed values of each element were removed, and then the content was calculated as an average value.

[0137] In addition, for the evaluation of powdering properties, a 45-degree V-bending test was conducted on 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 removed. The powdering property of the plating layer peeled off with this tape was evaluated on a 5-point scale. The specific evaluation criteria were determined as follows, and a score of 2 or more was evaluated as a pass.

Peel-off width less than 2 mm: 5 points

Peel-off width 2 mm or more and less than 3 mm: 4 points

Peel-off width 3 mm or more and less than 5 mm: 3 points

Peel-off width 5 mm or more and less than 7 mm: 2 points

Peel-off width 7 mm or more: 1 point

[Table 1]

Type	Steel Alloy Composition (wt%)												Others
	C	Si	Mn	P	S	Al	N	Cu	Ni	Mo	Sn	Ti	
A	0.0009	0.002	0.053	0.002	0.0014	0.025	0.0015	0.820	0.670	0.840	0.340	0.013	Hf 0.005
B	0.0016	0.004	0.095	0.005	0.0040	0.028	0.0036	0.630	0.850	0.450	0.210	0.033	Nb 0.058 Y 0.005
C	0.0027	0.013	0.161	0.013	0.0080	0.032	0.0055	0.460	0.360	0.440	0.100	0.052	W 0.02
D	0.0038	0.024	0.203	0.024	0.0150	0.033	0.0061	0.390	0.250	0.320	0.050	0.057	Mg 0.002
E	0.0157	0.027	0.255	0.036	0.0180	0.035	0.0086	0.270	0.230	0.210	0.040	0.077	Cr 0.25 Zr 0.02
F	0.0281	0.028	0.291	0.047	0.0240	0.033	0.0097	0.150	0.110	0.110	0.010	0.094	B 0.0022 Sb 0.002
G	0.0499	0.033	0.370	0.063	0.0350	0.032	0.0164	0.002	0.003	0.002	0.001	0.143	Ca 0.004 REM 0.001
XA	0.0742	0.022	0.238	0.027	0.0240	0.028	0.0043	0.170	0.220	0.150	0.022	0.039	-
XB	0.0022	0.829	0.249	0.026	0.0230	0.025	0.0057	0.210	0.220	0.220	0.023	0.051	-
XC	0.0020	0.022	1.062	0.019	0.0320	0.033	0.0064	0.230	0.230	0.170	0.021	0.056	-
XD	0.0022	0.024	0.223	0.018	0.0310	0.532	0.0067	0.240	0.170	0.160	0.016	0.062	-
XE	0.0023	0.023	0.224	0.022	0.0280	0.031	0.0041	0.170	0.190	0.180	0.018	0.294	-
XF	0.0025	0.027	0.208	0.024	0.0240	0.034	0.0056	1.090	0.210	0.230	0.023	0.050	-
XG	0.0023	0.022	0.316	0.025	0.0270	0.032	0.0052	0.250	1.050	0.250	0.020	0.046	-
XH	0.0024	0.025	0.279	0.027	0.0230	0.027	0.0047	0.310	0.240	1.220	0.025	0.043	-
XI	0.0022	0.023	0.239	0.025	0.0220	0.025	0.0044	0.330	0.230	0.180	0.519	0.038	-
In Table 1, REM refers to REM excluding Y.													

EP 4 826 065 A1

[Table 2]

Steel Type	Reheating Temp. (°C)	Finish 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	84	48	860	40	0.97	1
B	1160	880	780	0.5	64	41	860	40	0.55	2
A	1280	930	820	0.4	76	45	860	600	0.93	3
B	1060	780	400	0.5	76	39	860	20	0.99	4
A	1160	880	750	0.5	76	58	880	40	0.76	5
B	1160	880	750	0.4	76	33	880	40	0.78	6
B	1320	950	750	0.5	76	26	880	40	0.80	7
B	880	630	470	0.6	76	24	880	40	0.97	8
B	1270	930	820	0.7	76	31	880	40	0.93	9
B	1160	880	680	0.6	76	33	880	40	0.98	10
B	1160	880	750	0.9	48	32	880	40	0.34	11
B	1160	880	700	1.0	76	34	580	40	0.15	12
B	1160	880	750	0.8	76	35	980	40	0.99	13
B	1160	880	750	0.9	76	24	880	5	0.13	14
B	1160	880	750	1.0	76	25	880	1000	0.98	15
B	1160	880	700	0.1	76	18	860	40	0.92	16
B	1160	880	700	10.6	76	21	860	40	0.98	17
B	1160	880	700	0.5	76	1	880	40	0.93	18
B	1160	880	750	0.7	76	62	880	40	0.36	19
C	1050	880	750	0.6	76	25	860	40	0.81	20
D	1050	880	750	1.2	76	17	920	40	0.92	21
E	1160	880	720	1.0	76	9	900	40	0.65	22
F	1250	880	780	2.7	76	5	900	40	0.72	23
G	1160	880	780	5.6	76	2	880	40	0.73	24
XA	1160	880	750	1.0	76	17	880	40	0.44	25
XB	1160	880	750	0.8	76	22	880	40	0.56	26
XC	1160	880	750	0.7	76	23	880	40	0.48	27
XD	1160	880	750	0.9	76	22	880	40	0.47	28
XE	1160	880	750	0.6	76	25	880	40	0.52	29
XF	1160	880	750	0.5	76	26	880	40	0.56	30
XG	1160	880	750	0.7	76	18	880	40	0.53	31
XH	1160	880	750	0.8	76	16	880	40	0.55	32
XI	1160	880	750	0.6	76	21	880	40	0.57	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.

[Table 3]

	Specimen No.	A/B	Cold-Rolled Steel Sheet Grain Size (μm)	TS $\times$ EI (GPa%)	r-value $\times$ EI (%)	Powdering Property
5	1	0.55	46	29	192	4
	2	0.53	21	17	91	4
	3	31.16	55	42	213	1
10	4	0.49	8	3.5	17	4
	5	0.18	35	27	198	5
	6	0.35	33	23	162	4
	7	30.84	34	28	157	1
15	8	0.51	7	3.5	16	3
	9	31.70	54	33	207	1
	10	0.45	9	3.6	18	3
	11	0.54	11	5.4	17	3
20	12	0.23	4	3	11	3
	13	31.02	53	34	212	1
	14	0.21	5	3.4	15	3
25	15	30.57	52	32	206	1
	16	30.82	51	31	205	1
	17	0.37	10	3.2	17	4
	18	30.28	53	37	219	1
30	19	0.36	12	3.5	13	4
	20	0.85	28	22	133	4
	21	2.53	23	17	92	4
35	22	8.52	18	12	64	4
	23	16.8	15	6.7	33	3
	24	28.6	7	4.6	25	3
	25	16.5	5	2.9	15	2
40	26	26.3	9	3.4	13	2
	27	24.6	7	3.6	17	3
	28	21.7	9	2.5	12	2
45	29	22.3	5	2.3	16	3
	30	22.5	11	3.7	15	2
	31	25.8	12	3.2	14	2
	32	16.1	11	2.5	13	3
50	33	17.3	13	2.2	17	2
In Table 3, A/B means the value (A/B) obtained by dividing the average content (wt%, A) of (Cu+Ni+Mo+Sn) in the surface layer portion by the average content (wt%, B) of (Cu+Ni+Mo+Sn) in the central portion.						

55 **[0138]** As shown in Tables 1 to 3, in the case of 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, formability, and the like were all excellent.

[0139] On the other hand, in the case of specimens that deviated from one or more of the alloy composition and

manufacturing conditions of the present disclosure, at least one or more physical properties such as strength, formability, and plating adhesion were inferior because the grains of the microstructure were not formed as intended or because a specific element was unevenly distributed.

[0140] As such, the present disclosure is technically significant in that it is possible to achieve both excellent formability and plating adhesion by controlling the grain size characteristics and the content ratio of specific elements depending on the position in the thickness direction.

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%, copper (Cu): more than 0% to 1.000%, nickel (Ni): more than 0% to 1.000%, molybdenum (Mo): more than 0% to 1.000%, and tin (Sn): more than 0% to 0.5000%, at least one selected from the following groups (i) to (vi), with a balance being Fe and other unavoidable impurities:

(i) chromium (Cr): 0 to 1.000%;

(ii) at least one 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) at least one 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) at least one of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%;

(v) at least one of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%; and

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

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

wherein the central portion refers to a t/2 point in a thickness direction, and the surface layer portion refers to a region from a surface to an inflection point, which is a point where a concentration changes when concentration gradients of Cu, Ni, Mo, and Sn are measured in the thickness direction from the surface, wherein the inflection point refers to a point corresponding to 99% of the (Cu+Ni+Mo+Sn) content at the central portion in a measured value of the concentration gradient when a (Cu+Ni+Mo+Sn) content at an outermost surface is greater than the (Cu+Ni+Mo+Sn) content at the central portion, or refers to a point corresponding to 1% of the (Cu+Ni+Mo+Sn) content at the central portion in the measured value of the concentration gradient when the (Cu+Ni+Mo+Sn) content at the outermost surface is smaller than the (Cu+Ni+Mo+Sn) content at the central portion, 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 the steel sheet has a microstructure of a single ferrite phase.

4. The steel sheet of claim 1, wherein the steel sheet has a product (TS×EI) of tensile strength (TS) and elongation (EI) of 4.0 to 30.0 GPa·%.

5. The steel sheet of claim 1, wherein the steel sheet has a product (r-value×EI) of Lankford value (r-value) and elongation of 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 the plating layer has a powdering peel-off width of 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%, 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%, copper (Cu): more than 0% to 1.000%, nickel (Ni): more than 0% to 1.000%, molybdenum (Mo): more than 0% to 1.000%, and tin (Sn): more than 0% to 0.5000%, and at least one selected from the following groups (i) to (vi), with a balance being Fe and other unavoidable impurities:

- (i) chromium (Cr): 0 to 1.000%;
- (ii) at least one 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) at least one 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) at least one of tungsten (W): 0 to 0.50% and zirconium (Zr): 0 to 0.50%;
- (v) at least one of antimony (Sb): 0 to 0.5000% and cobalt (Co): 0 to 0.5000%; and
- (vi) at least one 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 at 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 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 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 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 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 of claim 12, wherein the hot-dip plating is hot-dip galvanizing in a temperature range of 440 to 520°C.
- 14. The method of claim 13, further comprising performing an alloying heat treatment after the hot-dip galvanizing.
- 15. A steel sheet manufactured by the manufacturing method 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 17, wherein the plating layer has a powdering peel-off width of less than 7 mm.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020398

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/12(2006.01)i; **C22C 38/08**(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 38/12(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), 구리(copper), 니켈
(nickel), 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 2015-147968 A (JFE STEEL CORP.) 20 August 2015 (2015-08-20) See paragraph [0048] and claims 1-3.	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 2004-143470 A (NIPPON STEEL CORP.) 20 May 2004 (2004-05-20) See paragraph [0032] 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

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

* Special categories of cited documents:

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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	Date of mailing of the international search report
05 March 2025	05 March 2025
Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208	
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020398

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REFERENCES CITED IN THE DESCRIPTION

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