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(54) **COLD-ROLLED STEEL SHEETS AND PLATED STEEL SHEETS, AND METHOD FOR MANUFACTURING SAME**

(57) The present invention relates to steel sheets suitable for a variety of uses including automobile parts, more specifically to cold-rolled steel sheets and plated

steel sheets containing residual elements and having good hole expansion ratio and plating adhesiveness, and to a manufacturing method thereof.

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Description

Technical Field

[0001] The present disclosure relates to a steel sheet suitable for various applications including automobile parts, and more particularly, to a cold-rolled steel sheet and a plated steel sheet containing residual elements and having an excellent hole expansion ratio and plating adhesion, and methods for manufacturing the same.

Background Art

[0002] In order to address the global climate crisis, automobile manufacturers are gradually requiring steelmakers to supply automobile steel sheets manufactured with reduced CO₂ emissions, with the goal of achieving carbon neutrality by 2050. For this reason, recently, steelmakers have been developing automobile steel sheets manufactured with reduced CO₂ emissions through recycling of steel scrap using existing blast furnace-basic oxygen furnace steelmaking methods or electric furnace steelmaking methods.

[0003] When steel scrap is used as a raw material, residual elements (tramp elements), such as Cu and Ni, contained in the steel scrap are difficult to remove during refining, and are therefore contained in the steel after refining. Since these residual elements may degrade the properties of the steel or deteriorate surface quality, high-grade thin sheet products represented by automobile steel sheets have so far been manufactured by a method in which hot metal is used as a main raw material, C and N in the steel are greatly reduced in a general blast furnace-basic oxygen furnace process, and the content of residual elements is strictly controlled.

[0004] Meanwhile, technologies for manufacturing automobile steel sheets having excellent formability from electric furnace steel containing residual elements using an electric furnace steelmaking method have been proposed as follows.

[0005] Patent Documents 1 and 2 disclose technologies for manufacturing cold-rolled steel sheets having excellent hole expansion ratio (burring properties). Specifically, the steel sheets disclosed therein are cold-rolled steel sheets having excellent burring properties despite containing a large amount of residual elements. However, the above technologies do not consider at all an object of improving inferior plating adhesion of the steel sheet or means for achieving the object.

[0006] As described above, although technologies for manufacturing automobile steel sheets containing residual elements have been proposed, an automobile steel sheet having both improved hole expansion ratio and improved plating adhesion despite containing residual elements has not yet been developed.

(Patent Document 1) Japanese Patent No. 6179698

(Patent Document 2) Japanese Patent Laid-Open Publication No. 2004-250749

Summary of Invention

Technical Problem

[0007] An aspect of the present disclosure is to provide a cold-rolled steel sheet and a plated steel sheet having improved hole expansion ratio and plating adhesion despite containing residual elements, and methods for manufacturing the same, in the manufacture of a steel sheet for automobiles by recycling steel scrap.

[0008] The object of the present disclosure is not limited to the above description. Those skilled in the art to which the present disclosure pertains will have no difficulty in understanding additional objects of the present disclosure from the overall content of the present specification.

Solution to Problem

[0009] According to an aspect of the present disclosure, a cold-rolled steel sheet contains, by wt%, greater than 0% to 0.2500% of carbon (C), greater than 0% to 0.700% of silicon (Si), greater than 0% to 1.800% of manganese (Mn), greater than 0% to 0.700% of aluminum (Al), 0.080% or less of phosphorus (P), 0.050% or less of sulfur (S), 0.0300% or less of nitrogen (N), 1.000% or less of copper (Cu), 1.000% or less of nickel (Ni), 1.000% or less of chromium (Cr), one or more selected from 0.050% or less of magnesium (Mg), 0.050% or less of calcium (Ca), 0.050% or less of rare earth elements (REM) excluding yttrium (Y), 0.50% or less of tungsten (W), 0.50% or less of zirconium (Zr), 0.500% or less of antimony (Sb), 0.500% or less of tin (Sn), 0.500% or less of cobalt (Co), 0.200% or less of yttrium (Y), and 0.200% or less of hafnium (Hf), one or more selected from 0.220% or less of titanium (Ti), 0.220% or less of niobium (Nb), 0.220% or less of vanadium (V), 1.000% or less of molybdenum (Mo), and 0.0200% or less of boron (B), and the

balance of Fe and inevitable impurities.

[0010] According to an embodiment in the present disclosure, a cold-rolled steel sheet in which A/B satisfies 0.15 to 30.00 is provided, where A represents an average content (wt%) of (Cu+Cr+Ni+Sn) in a surface layer portion of the cold-rolled steel sheet, and B represents an average content (wt%) of (Cu+Cr+Ni+Sn) in a central portion.

[0011] The cold-rolled steel sheet of the present disclosure may have excellent hole expansion ratio and may also have excellent plating adhesion when subjected to a subsequent plating process.

[0012] In an embodiment in the present disclosure, when one or more of titanium (Ti), niobium (Nb), and vanadium (V) are added, a total content of Ti, Nb, and V (Ti+Nb+V) in the cold-rolled steel sheet may be 0.22% or less.

[0013] In an embodiment in the present disclosure, a relationship between tensile strength (TS) and elongation (El) of the cold-rolled steel sheet may satisfy the following Relational Expression 1.

[Relational Expression 1]

$$0.6 \times 10^6 \leq TS^2 \times \sqrt{El} \leq 2.3 \times 10^6$$

[0014] (The unit of Relational Expression 1 is (MPa)²%^{0.5}.)

[0015] In an embodiment in the present disclosure, a relationship between tensile strength (TS) and hole expansion ratio (HER) of the cold-rolled steel sheet may satisfy the following Relational Expression 2.

[Relational Expression 2]

$$0.9 \times 10^6 \leq TS^2 \times \sqrt{HER} \leq 3.8 \times 10^6$$

[0016] (The unit of Relational Expression 2 is (MPa)²%^{0.5}.)

[0017] In an embodiment in the present disclosure, the cold-rolled steel sheet may have a yield ratio of 0.50 to 0.95.

[0018] According to another aspect of the present disclosure, a method for manufacturing a cold-rolled steel sheet includes: preparing a steel slab; heating the steel slab in a temperature range of 900 to 1,300°C; finish-rolling the heated steel slab in an austenite region at a temperature equal to or higher than an Ar3 transformation point or in a ferrite region at a temperature equal to or lower than the Ar3 transformation point to obtain a hot-rolled steel sheet; coiling the hot-rolled steel sheet in a temperature range of 330 to 750°C; cooling the coiled hot-rolled steel sheet at a rate of 0.2 to 10°C/min to a temperature range of 250 to 300°C; cold-rolling the hot-rolled steel sheet after the cooling at a cold reduction ratio of 30 to 90% to obtain a cold-rolled steel sheet; and subjecting the cold-rolled steel sheet to annealing at 600°C or higher for 10 seconds or longer.

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

[0020] In an embodiment in the present disclosure, the annealing 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°C/s.

[0021] According to still another aspect of the present disclosure, there are provided a plated steel sheet including a zinc-based plating layer formed on at least one surface of a cold-rolled steel sheet, and a method for manufacturing a plated steel sheet by plating a cold-rolled steel sheet.

[0022] In an embodiment in the present disclosure, the cold-rolled steel sheet may be the above-described cold-rolled steel sheet.

[0023] In an embodiment in the present disclosure, the plating may be performed by a hot-dip plating or electroplating process.

[0024] In an embodiment in the present disclosure, the hot-dip plating may include hot-dip galvanizing performed in a temperature range of 440 to 520°C, and the method may optionally further include performing alloying heat treatment after the hot-dip galvanizing.

Advantageous Effects of Invention

[0025] According to the present disclosure, a steel sheet (a cold-rolled steel sheet or a plated steel sheet) for automobiles having improved hole expansion ratio and plating adhesion despite containing residual elements may be provided.

[0026] The steel sheet of the present disclosure is manufactured by recycling steel scrap, and thus has an excellent effect of reducing CO₂ emissions when applied as a material for automobile bodies and the like.

[0027] Various and beneficial advantages and effects of the present disclosure are not limited to those described above, and may be more readily understood in the course of describing specific embodiments in the present disclosure.

Best Mode for Invention

[0028] The terminology used herein is merely for referring to particular embodiments and is not intended to limit the present disclosure. Singular forms used herein include plural forms unless phrases clearly indicate a contrary meaning.

[0029] The term "comprising" used in the specification specifies specific properties, regions, integers, steps, operations, elements, and/or components, and does not exclude the presence or addition of other specific properties, regions, integers, steps, operations, elements, components, and/or groups.

[0030] Unless defined otherwise, all terms, including technical terms and scientific terms, used herein have the same meanings as commonly understood by those skilled in the art to which the present disclosure pertains. Terms defined in a generally used dictionary are additionally interpreted as having meanings consistent with related technical documents and the contents disclosed herein, and are not interpreted as having ideal or overly formal meanings unless otherwise defined.

[0031] Hereinafter, a cold-rolled steel sheet according to an aspect of the present disclosure, particularly a cold-rolled steel sheet having excellent hole expansion ratio and plating adhesion, will be described in detail. In the present disclosure, it should be noted that the contents of respective elements are expressed in wt% unless otherwise specified. In addition, ratios of grains or structures are based on area unless otherwise specifically indicated.

[0032] A cold-rolled steel sheet according to an aspect of the present disclosure may contain, by wt%, greater than 0% to 0.2500% of carbon (C), greater than 0% to 0.700% of silicon (Si), greater than 0% to 1.800% of manganese (Mn), greater than 0% to 0.700% of aluminum (Al), 0.080% or less of phosphorus (P), 0.050% or less of sulfur (S), 0.0300% or less of nitrogen (N), 1.000% or less of copper (Cu), 1.000% or less of nickel (Ni), 1.000% or less of chromium (Cr), one or more selected from 0.050% or less of magnesium (Mg), 0.050% or less of calcium (Ca), 0.050% or less of rare earth elements (REM) excluding yttrium (Y), 0.50% or less of tungsten (W), 0.50% or less of zirconium (Zr), 0.500% or less of antimony (Sb), 0.500% or less of tin (Sn), 0.500% or less of cobalt (Co), 0.200% or less of yttrium (Y), and 0.200% or less of hafnium (Hf), and one or more selected from 0.220% or less of titanium (Ti), 0.220% or less of niobium (Nb), 0.220% or less of vanadium (V), 1.000% or less of molybdenum (Mo), and 0.0200% or less of boron (B).

[0033] Hereinafter, the reason for limiting the alloy composition of the cold-rolled steel sheet provided by the present disclosure as described above will be described in detail.

Carbon (C): greater than 0% to 0.2500%

[0034] Carbon (C) is an element effective for securing the strength of steel, and when Ti, Nb, V, and the like are present in the steel, C combines with these elements to form precipitates, which is advantageous for imparting strength to the steel sheet.

[0035] In an embodiment in the present disclosure, when a content of C exceeds 0.2500%, it becomes difficult to secure weld strength of a welded portion during welding. Therefore, C may be contained in an amount of 0.2500% or less. In another embodiment in the present disclosure, C may be contained in an amount of 0.2300% or less or 0.2000% or less.

[0036] Meanwhile, C is an essential element in manufacturing steel, and the content of C is greater than 0%. However, in an embodiment in the present disclosure, when the content of C is less than 0.0010%, the effect achieved by reducing C is hardly obtained, and rather, steelmaking costs increase, which is not preferable. Therefore, C may be contained in an amount of 0.0010% or more. In another embodiment in the present disclosure, C may be contained in an amount of 0.0015% or more or 0.0020% or more.

Silicon (Si): greater than 0% to 0.700%

[0037] Silicon (Si) is an element having an effect of improving strength through solid-solution strengthening, and is useful for strengthening ferrite and homogenizing the structure, thereby improving formability. In addition, Si is an element necessary for deoxidation during steelmaking.

[0038] In an embodiment in the present disclosure, when a content of Si exceeds 0.700%, plating defects such as unplated portions may be caused during plating, and weldability of the steel sheet may be impaired. Accordingly, Si may be contained in an amount of 0.700% or less. In another embodiment in the present disclosure, Si may be 0.600% or less.

[0039] Meanwhile, in an embodiment in the present disclosure, Si may be contained in an amount greater than 0%, and the content of Si may be 0.001% or more in consideration of manufacturing costs.

Manganese (Mn): greater than 0% to 1.800%

[0040] Manganese (Mn) is an element useful for simultaneously improving the strength and ductility of steel.

[0041] In an embodiment in the present disclosure, when a content of Mn exceeds 1.800%, transformation from austenite into low-temperature transformation phases such as martensite or bainite is promoted, and a yield ratio of the steel sheet decreases. Accordingly, Mn may be 1.800% or less. In another embodiment in the present disclosure, Mn may be 1.790% or less or 1.780% or less.

[0042] Meanwhile, in an embodiment in the present disclosure, Mn may be contained in an amount greater than 0%, and the content of Mn may be 0.001% or more in consideration of manufacturing costs.

Aluminum (Al): greater than 0% to 0.700%

[0043] Aluminum (Al) is an element that combines with oxygen (O) in steel and performs deoxidation. In addition, similarly to Si, Al is an element that strengthens ferrite, homogenizes the structure, and improves formability.

[0044] In an embodiment in the present disclosure, when a content of Al exceeds 0.700%, plating defects such as unplated portions may occur in the plating process, and weldability of the steel sheet may deteriorate. Therefore, Al may be contained in an amount of 0.700% or less. In another embodiment in the present disclosure, Al may be contained in an amount of 0.600% or less.

[0045] Meanwhile, in an embodiment in the present disclosure, Al may be contained in an amount greater than 0%, and the content of Al may be 0.001% or more in consideration of manufacturing costs.

Phosphorus (P): 0.080% or less

[0046] Phosphorus (P) is an element added to improve the strength of steel. In an embodiment in the present disclosure, when a content of P exceeds 0.080%, impact toughness of the steel may deteriorate. According to another embodiment in the present disclosure, P may be contained in an amount of 0.070% or less.

[0047] Meanwhile, in an embodiment in the present disclosure, P may be contained in an amount greater than 0%, and may be contained in an amount of 0.001% or more in consideration of manufacturing costs.

Sulfur (S): 0.050% or less

[0048] Sulfur (S) is an element inevitably added during a steel manufacturing process, and impairs ductility of steel by combining with Mn in the steel to form MnS inclusions. Therefore, in an embodiment in the present disclosure, a content of S may be limited to 0.050% or less. In another embodiment in the present disclosure, S may be contained in an amount of 0.040% or less.

[0049] Meanwhile, since S may be inevitably contained in steel, the content of S may be greater than 0%. In an embodiment in the present disclosure, when the content of S is controlled to less than 0.001%, manufacturing costs may significantly increase, and thus S may be contained in an amount of 0.001% or more.

Nitrogen (N): 0.0300% or less

[0050] Nitrogen (N) is an element inevitably added during a steel manufacturing process, and is an element that causes cracking of a slab by forming nitrides during continuous casting. In consideration thereof, according to an embodiment in the present disclosure, N may be contained in an amount of 0.0300% or less.

[0051] Meanwhile, when the content of N is controlled to less than 0.0010%, manufacturing costs may significantly increase, and thus the content of N may be limited to 0.0010% or more.

Copper (Cu): 1.000% or less and Nickel (Ni): 1.000% or less

[0052] Copper (Cu) and nickel (Ni) are elements that stabilize austenite and suppress corrosion. In addition, Cu and Ni are elements useful for suppressing hydrogen delayed fracture by being enriched on a surface of a steel sheet and preventing hydrogen from penetrating into the steel.

[0053] In an embodiment in the present disclosure, when contents of Cu and Ni are excessive, formability may deteriorate, and thus the contents thereof may each be limited to 1.000% or less. In another embodiment in the present disclosure, Cu and Ni may each be contained in an amount of 0.900% or less.

[0054] Meanwhile, in an embodiment in the present disclosure, Cu and Ni may each be contained in an amount greater than 0%, and may each be contained in an amount of 0.001% or more in order to sufficiently obtain the effects of these elements.

Chromium (Cr): 1.000% or less

[0055] Chromium (Cr) is an element that suppresses decomposition of austenite and stabilizes austenite during alloying of a manufactured steel sheet.

[0056] In an embodiment in the present disclosure, when a content of Cr is excessive, formability may deteriorate, and thus the content of Cr may be limited to 1.000% or less in consideration thereof. In another embodiment in the present disclosure, Cr may be contained in an amount of 0.900% or less.

[0057] Meanwhile, in an embodiment in the present disclosure, Cr may be contained in an amount greater than 0%, but may be contained in an amount of 0.001% or more in order to sufficiently obtain the effect of Cr.

[0058] The steel sheet of the present disclosure may contain one or more of the following residual elements in addition to the above-described alloy composition.

[0059] First, the steel sheet may contain one or more selected from 0.050% or less of magnesium (Mg), 0.050% or less of calcium (Ca), 0.050% or less of rare earth elements (REM) excluding yttrium (Y), 0.50% or less of tungsten (W), 0.50% or less of zirconium (Zr), 0.500% or less of antimony (Sb), 0.500% or less of tin (Sn), 0.500% or less of cobalt (Co), 0.200% or less of yttrium (Y), and 0.200% or less of hafnium (Hf).

[0060] Magnesium (Mg): 0.050% or less, Calcium (Ca): 0.050% or less, and Rare earth elements (REM) excluding yttrium (Y): 0.050% or less

[0061] Magnesium (Mg), calcium (Ca), and rare earth elements (REM) excluding yttrium (Y) are elements that improve ductility of steel by spheroidizing sulfides in the steel. In an embodiment in the present disclosure, when each of the above-described elements is present in an amount exceeding 0.050%, the above-described effect may be saturated, and manufacturing costs may increase. Therefore, the contents thereof may each be limited to 0.050% or less.

[0062] In general, rare earth elements (REM) refer to a total of 17 metallic elements, such as scandium (Sc), yttrium (Y), lanthanum (La), and cerium (Ce). According to an embodiment in the present disclosure, since the content of yttrium (Y) is separately limited below, it is noted that, in an embodiment in the present disclosure, REM refers to 16 elements excluding Y.

Tungsten (W): 0.50% or less and Zirconium (Zr): 0.50% or less

[0063] Tungsten (W) and zirconium (Zr) are elements that improve hardenability of steel and increase the strength of the steel. According to an embodiment in the present disclosure, when W and Zr are present excessively, the above-described effects may be saturated, and manufacturing costs may increase. Therefore, the contents thereof may each be limited to 0.50% or less.

Antimony (Sb): 0.500% or less, Tin (Sn): 0.500% or less, and Cobalt (Co): 0.500% or less

[0064] Antimony (Sb), tin (Sn), and cobalt (Co) are elements that improve plating wettability and plating adhesion of steel. In an embodiment in the present disclosure, when contents of the elements each exceed 0.500%, brittleness of the steel may increase, thereby causing cracks during hot working or cold working. Therefore, the content of each element may be limited to 0.500% or less. According to another embodiment in the present disclosure, Sb, Sn, and Co may each be contained in an amount of 0.400% or less. Meanwhile, in order to sufficiently obtain the intended effects through the inclusion of these elements, each of these elements may be contained in an amount of 0.0005% or more.

Yttrium (Y): 0.200% or less and Hafnium (Hf): 0.200% or less

[0065] Yttrium (Y) and hafnium (Hf) are elements improving corrosion resistance of steel. In an embodiment in the present disclosure, when contents of the elements each exceed 0.200%, ductility of the steel may decrease. Therefore, the content of each element may be limited to 0.200% or less.

[0066] In addition, the steel sheet of the present disclosure may further contain, in addition to the above-described components, one or more selected from 0.220% or less of titanium (Ti), 0.220% or less of niobium (Nb), 0.220% or less of vanadium (V), 1.000% or less of molybdenum (Mo), and 0.0200% or less of boron (B).

Titanium (Ti): 0.220% or less, Niobium (Nb): 0.220% or less, and Vanadium (V): 0.220% or less

[0067] Titanium (Ti), niobium (Nb), and vanadium (V) are elements that form precipitates in steel, and the formation of the precipitates may improve the strength and impact toughness of the steel. In particular, Ti, Nb, and V may prevent deterioration in formability caused by solid-solution C and solid-solution N by precipitating solid-solution C and solid-solution N in the steel as carbides, nitrides, and the like.

[0068] In an embodiment in the present disclosure, when the elements are added, each of the elements may be added in an amount of 0.001% or more, and the above-described effects may be obtained therefrom. However, when the content of each element exceeds 0.220%, the addition effect may be saturated and manufacturing costs may increase. Therefore, an upper limit of each element may be limited to 0.220%. According to another embodiment in the present disclosure, the elements may each be contained in an amount of 0.200% or less.

[0069] Meanwhile, according to an embodiment in the present disclosure, when one or more of Ti, Nb, and V are added, a total content of these elements (Ti+Nb+V) may be 0.220% or less. According to another embodiment, the total content of the elements may be 0.200% or less.

Molybdenum (Mo): 1.000% or less

[0070] Molybdenum (Mo), similarly to Cr mentioned above, is an element that suppresses decomposition of austenite and stabilizes austenite during alloying of a manufactured steel sheet.

[0071] In an embodiment in the present disclosure, when a content of Mo is excessive, formability may deteriorate, and thus the content of Mo may be limited to 1.000% or less in consideration thereof. According to another embodiment in the present disclosure, Mo may be contained in an amount of 0.900% or less. Meanwhile, in an embodiment in the present disclosure, Mo may be contained in an amount of 0.001% or more in order to obtain the effect of adding Mo, and thus a lower limit thereof may be limited to 0.001%.

Boron (B): 0.0200% or less

[0072] Boron (B) is an element that improves hardenability of steel, increases strength, and suppresses nucleation at grain boundaries.

[0073] In an embodiment in the present disclosure, when a content of B exceeds 0.0200%, deep drawability of the steel may deteriorate. Therefore, when B is added, the content of B may be limited to 0.0200% or less. According to another embodiment, B may be contained in an amount of 0.0100% or less. Meanwhile, in an embodiment in the present disclosure, B may be contained in an amount of 0.0001% or more in order to obtain the effect of adding B, and according to another embodiment, B may be contained in an amount of 0.0005% or more or 0.0010% or more.

[0074] In an embodiment in the present disclosure, the cold-rolled steel sheet may contain the balance of Fe and other inevitable impurities in addition to the above-described components. However, in a typical manufacturing process, unintended impurities may inevitably be introduced from raw materials or the surrounding environment, and thus such impurities cannot be completely excluded. Since these impurities are known to those skilled in the art, not all details thereof are specifically mentioned in the present specification. In addition, the addition of effective components other than the above-described components is not completely excluded.

[0075] According to an embodiment in the present disclosure, contents of some residual elements contained at specific points in a thickness direction of the cold-rolled steel sheet may be controlled as follows, and therefore, improvements in hole expansion ratio, powdering properties, and the like of the steel sheet may be achieved.

[0076] Specifically, in an embodiment in the present disclosure, A/B may satisfy 0.15 to 30.00, where A represents an average content (wt%) of (Cu+Cr+Ni+Sn) in a surface layer portion of the cold-rolled steel sheet, and B represents an average content (wt%) of (Cu+Cr+Ni+Sn) in a central portion of the cold-rolled steel sheet.

[0077] In an embodiment in the present disclosure, A/B is significant in that it is used as an indicator representing hole expansion ratio and powdering properties of the steel sheet. When the value of A/B is less than 0.15 or exceeds 30.00, specific residual elements contained in the steel may not be uniformly distributed.

[0078] Here, the central portion refers to a point t/2 in the thickness direction. In addition, the surface layer portion may refer to a region extending from the surface to a point at which concentrations change (or rapidly change) when concentrations of Cu, Cr, Ni, and Sn are measured in the thickness direction. As an example, when a content of (Cu+Cr+Ni+Sn) at the surface is greater than a content of (Cu+Cr+Ni+Sn) in the central portion, the surface layer portion may extend to a point corresponding to 99% of the content of (Cu+Cr+Ni+Sn) in the central portion in the measured concentration values. When the content of (Cu+Cr+Ni+Sn) at the surface is less than the content of (Cu+Cr+Ni+Sn) in the central portion, the surface layer portion may extend to a point corresponding to 1% of the content of (Cu+Cr+Ni+Sn) in the central portion in the measured concentration values. As a non-limiting example, the concentrations of the above-described elements may be measured using FE-SEM or a glow discharge spectrometer (GDS).

[0079] In an embodiment in the present disclosure, the microstructure of the cold-rolled steel sheet may include ferrite as a main phase, and, as an example, may be composed of ferrite in an area fraction of 75 to 98% and the balance of cementite.

[0080] In an embodiment in the present disclosure, when a ferrite phase is included in the microstructure of the cold-rolled steel sheet, if the area fraction is less than 75%, the hole expansion ratio may be inferior, whereas if the area

fraction exceeds 98%, strength may decrease.

[0081] In an embodiment in the present disclosure, ferrite may include both recrystallized ferrite and unrecrystallized ferrite, and the fraction ranges thereof are not particularly limited. It is noted that the fraction ranges will be naturally determined by the alloy composition and manufacturing process according to an embodiment in the present disclosure.

[0082] Meanwhile, it is not intended to exclude even an extremely small amount of impurity structure inevitably contained due to the process from the cold-rolled steel sheet according to an embodiment in the present disclosure, and such a structure is naturally included in the scope of the present disclosure. Here, the impurity structure is not particularly limited, but, as an example, may be pearlite, or a bainite or martensite phase formed at a low temperature.

[0083] The cold-rolled steel sheet according to an embodiment in the present disclosure has not only high strength but also excellent hole expansion ratio.

[0084] Specifically, according to an embodiment in the present disclosure, a relationship between tensile strength (TS) and elongation (El) of the cold-rolled steel sheet may satisfy the following Relational Expression 1, and a relationship between tensile strength (TS) and hole expansion ratio (HER) of the cold-rolled steel sheet may satisfy the following Relational Expression 2.

[Relational Expression 1]

$$0.6 \times 10^6 \leq TS^2 \times \sqrt{El} \leq 2.3 \times 10^6$$

[0085] (The unit of Relational Expression 1 is (MPa)²%^{0.5}.)

[Relational Expression 2]

$$0.9 \times 10^6 \leq TS^2 \times \sqrt{HER} \leq 3.8 \times 10^6$$

[0086] (The unit of Relational Expression 2 is (MPa)²%^{0.5}.)

[0087] In addition, the cold-rolled steel sheet according to an embodiment in the present disclosure may have a yield ratio in a range of 0.50 to 0.95.

[0088] Hereinafter, a plated steel sheet according to another aspect of the present disclosure will be described.

[0089] According to an embodiment in the present disclosure, the plated steel sheet includes a zinc-based plating layer formed on at least one surface of the cold-rolled steel sheet. In an embodiment in the present disclosure, the zinc-based plating layer is a plating layer containing zinc (Zn) as a main component, and a configuration of a plating layer commonly applied in the art may be equally applied. In this case, the zinc-based plating layer may also include an alloyed zinc-based plating layer obtained by alloying.

[0090] That is, the plated steel sheet according to an embodiment in the present disclosure 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.

[0091] In an embodiment in the present disclosure, the cold-rolled steel sheet including a zinc-based plating layer formed on at least one surface may be the cold-rolled steel sheet according to an embodiment in the present disclosure, and it is noted that the above description may be equally applied to the cold-rolled steel sheet.

[0092] Meanwhile, the cold-rolled steel sheet according to an embodiment in the present disclosure may have concentration gradients of specific elements, for example, residual elements Cu, Cr, Ni, and Sn, in a thickness direction from a surface. When a zinc-based plating layer is formed on at least one surface of such a cold-rolled steel sheet, the residual elements may further diffuse into the plating layer due to the influence of a temperature during plating or during alloying. Accordingly, in the plated steel sheet, the concentration gradients of the residual elements may be realized in the thickness direction of the base material from an interface between the base material, which is the base steel sheet, and the plating layer, or may be realized from an alloy layer formed at an interface portion between the base material and the plating layer.

[0093] That is, the residual elements may have the concentration gradients represented by A/B described above due to differences in diffusion rates of the residual elements diffusing toward a surface side of the steel sheet during a process of manufacturing the cold-rolled steel sheet, and such characteristics of the cold-rolled steel sheet also appear in the plated steel sheet.

[0094] The plated steel sheet according to an embodiment in the present disclosure has excellent powdering properties of the plating layer, and specifically, the plating layer may have a powdering peeling width of less than 7 mm.

[0095] Hereinafter, methods for manufacturing a cold-rolled steel sheet and a plated steel sheet according to still another aspect of the present disclosure will be described in detail.

[0096] First, the cold-rolled steel sheet according to an embodiment in the present disclosure may be obtained

through a series of processes, for example, processes of [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 a cold-rolled steel sheet and a plated steel sheet according to an embodiment in the present disclosure.

[0097] According to an embodiment in the present disclosure, a steel slab or an ingot may be manufactured through an electric furnace or a new blast furnace-basic oxygen furnace process, and raw materials used in the electric furnace or blast furnace-basic oxygen furnace process include pig iron together with steel scrap. Here, pig iron refers to hot metal obtained in a blast furnace-basic oxygen furnace process, a cold material thereof (corrugate), hot briquette iron (HBI), or the like.

[0098] In the case of an electric furnace, after tapping from the electric furnace, desulfurization may be performed by ladle refining, and desulfurization and vacuum degassing treatment in a subsequent process may be performed. In addition, steel obtained from the electric furnace may be adjusted to have the final desired alloy composition by adding alloy components while performing degassing treatment. Here, RH method and DH method are generally used as vacuum degassing treatment methods, but oxygen blowing may also be performed into a degassing vessel. Examples of oxygen blowing include an oxygen blowing method using a top-blowing lance.

[Steel slab heating]

[0099] After a steel slab is prepared, the steel slab may be heated. At this time, the steel slab may be an ingot. In an embodiment in the present disclosure, the steel slab may have the above-described alloy composition, and thus the above description applies to the alloy composition of the steel slab.

[0100] In an embodiment in the present disclosure, when the prepared steel slab or ingot is heated, a heating temperature may be in a range of 900 to 1,300°C. When the heating temperature exceeds 1,300°C, the steel may reach a melting point and melt. On the other hand, when the temperature is lower than 900°C, a rolling load may increase during subsequent hot rolling, thereby reducing hot rolling stability. In another embodiment in the present disclosure, the heating may be performed at 1,160°C or lower.

[Hot rolling]

[0101] The heated steel slab or ingot may be hot-rolled to obtain a hot-rolled steel sheet.

[0102] In an embodiment in the present disclosure, a finishing temperature during hot rolling may be either in an austenite region at a temperature equal to or higher than an Ar3 transformation point or in a ferrite region at a temperature equal to or lower than the Ar3 transformation point. However, when the finishing temperature is too low, a rolling load increases during hot rolling, and thus a lower limit of the temperature may be limited to 750°C or higher.

[Coiling]

[0103] The hot-rolled steel sheet obtained by the hot rolling may be coiled into a coil shape.

[0104] In an embodiment in the present disclosure, the coiling process may be performed in a temperature range of 330 to 750°C. When the temperature during coiling is lower than 330°C, non-uniformity may occur on a surface of the hot-rolled coil due to an excessively low temperature. On the other hand, when the temperature exceeds 750°C, an excessively thick scale may be formed on the hot-rolled surface. According to another embodiment in the present disclosure, the coiling process may be performed at 350°C or higher.

[Cooling]

[0105] The coiled hot-rolled steel sheet may be cooled while being uncoiled.

[0106] In an embodiment in the present disclosure, cooling after coiling may be performed to a temperature range of 250 to 300°C at a cooling rate of 0.2 to 10.0°C/min. By performing cooling at such a relatively slow cooling rate, grains in the microstructure may be uniformly obtained.

[0107] In an embodiment in the present disclosure, when a cooling rate during cooling is less than 0.2°C/min, the cooling rate needs to be excessively reduced, which may impose a burden on equipment, and grains may not be uniformly obtained. On the other hand, when the cooling rate exceeds 10.0°C/min, grains may become coarse.

[0108] In an embodiment in the present disclosure, when a cooling end temperature during cooling is lower than 250°C, a cooling time may become excessive, thereby reducing productivity. On the other hand, when the cooling end temperature exceeds 300°C, a load may be caused during subsequent cold rolling.

[Cold rolling]

[0109] The cooled uncoiled hot-rolled steel sheet may be cold-rolled to obtain a cold-rolled steel sheet.

[0110] In an embodiment in the present disclosure, cold rolling may be performed at a cold reduction ratio of 30 to 90%. When the cold reduction ratio is less than 30%, it may be difficult to achieve a target thickness, and shape correction of the steel sheet may be difficult. According to an embodiment in the present disclosure, an upper limit of the cold reduction ratio during cold rolling is not particularly limited. However, when the cold reduction ratio is excessively high, a cold rolling load may increase. In consideration thereof, the cold reduction ratio may be limited to 90% or less.

[Annealing]

[0111] The manufactured cold-rolled steel sheet may be subjected to annealing heat treatment.

[0112] In an embodiment in the present disclosure, the annealing heat treatment may be performed in a general continuous annealing furnace, and may be performed under conditions in which the cold-rolled steel sheet is heated to 600°C or higher and then heat-treated for 10 seconds or longer. When the temperature during the annealing heat treatment is lower than 600°C or the time is shorter than 10 seconds, fine precipitates may not be formed in the cold-rolled steel sheet subjected to annealing heat treatment, or the precipitates may not be uniformly distributed.

[0113] According to an embodiment in the present disclosure, upper limits of the temperature and time during the annealing heat treatment are not particularly limited. However, in consideration of the possibility of equipment problems caused by high-temperature annealing and inferior powdering properties, the upper limits may be set to 960°C and 15 minutes, respectively. That is, when the temperature during the annealing heat treatment is excessively high or heat treatment is performed for a long time, powdering properties of a plated steel sheet obtained by a subsequent plating process may be inferior.

[0114] Meanwhile, when the cold-rolled steel sheet is heated to a temperature for annealing heat treatment, according to an embodiment in the present disclosure, the heating may be performed at a heating rate of 2 to 60°C/s. When the heating rate during the heating is too slow or excessively fast, fine precipitates may not be formed, or the precipitates may not be uniformly distributed.

[0115] The cold-rolled steel sheet manufactured through the series of processes according to an embodiment in the present disclosure may have the targeted strength and hole expansion ratio.

[0116] In particular, a relationship between tensile strength (TS) and elongation (EI) of the cold-rolled steel sheet according to an embodiment in the present disclosure may satisfy the following Relational Expression 1, and a relationship between tensile strength (TS) and hole expansion ratio (HER) of the cold-rolled steel sheet may satisfy the following Relational Expression 2.

[Relational Expression 1]

$$0.6 \times 10^6 \leq TS^2 \times \sqrt{EI} \leq 2.3 \times 10^6$$

[0117] (The unit of Relational Expression 1 is (MPa)^{2%}0.5.)

[Relational Expression 2]

$$0.9 \times 10^6 \leq TS^2 \times \sqrt{HER} \leq 3.8 \times 10^6$$

[0118] (The unit of Relational Expression 2 is (MPa)^{2%}0.5.)

[0119] Meanwhile, according to an aspect of the present disclosure, a plated steel sheet may be obtained by plating a cold-rolled steel sheet, and the cold-rolled steel sheet at this time may be a cold-rolled steel sheet manufactured through the series of processes according to an embodiment in the present disclosure. Accordingly, the plated steel sheet may include a plating layer formed on at least one surface of the cold-rolled steel sheet.

[0120] In an embodiment in the present disclosure, the plating may be a hot-dip plating or electroplating process, and each plating process may be performed under conditions commonly used in the art.

[0121] As an example, the hot-dip plating may be performed by immersing the cold-rolled steel sheet after the annealing heat treatment in a hot-dip galvanizing bath containing zinc as a main component. Since conditions during the hot-dip galvanizing may be conventional conditions, the conditions are not specifically limited in the present specification. However, as one embodiment, GI hot-dip plating may be performed under conventional conditions in a temperature range of 440 to 520°C.

[0122] In addition, according to an embodiment in the present disclosure, a galvanized steel sheet (GA) may be

obtained by selectively subjecting the plated steel sheet including the zinc-based plating layer formed thereon to alloying heat treatment. The alloying heat treatment may also be performed under conventional conditions and therefore is not specifically limited. However, as one example, the alloying heat treatment may be performed in a temperature range of 500 to 560°C.

[0123] In addition, as an example, the electroplating may be performed by placing a base steel sheet (cold-rolled steel sheet) at a negative electrode of a vertical plating cell-type electroplating simulator and then circulating a plating solution containing zinc (Zn), thereby forming a zinc-based plating layer on at least one surface of the base steel sheet (cold-rolled steel sheet).

Mode for Invention

[0124] Hereinafter, the present disclosure will be described more specifically with reference to Examples. However, it should be noted that the following Examples are only for illustrating the present disclosure in more detail 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 recited in the claims and matters reasonably inferred therefrom.

(Examples)

[0125] After steel slabs having the alloy compositions shown in Table 1 were prepared, steel sheets (cold-rolled steel sheets) were obtained by subjecting the steel slabs to a series of processes under the conditions shown in Table 2. At this time, cooling after coiling was performed to a temperature range of 250 to 300°C.

[0126] The steel slabs were obtained through the following process. First, steel scrap blended with hot metal from an existing blast furnace was charged into an electric furnace to obtain molten steel. Then, the molten steel was transferred to a ladle and subjected to vacuum degassing treatment in an RH degasser (0.1 torr), while alloy components were added to prepare molten steel having the intended composition. Thereafter, the molten steel was manufactured into a slab by continuous casting.

[0127] The microstructure and mechanical properties of each cold-rolled steel sheet were measured and evaluated. All results are shown in Table 3.

[0128] First, in order to measure the microstructure, a specimen was taken from t/4 in the thickness direction of each steel sheet (where t means the thickness (mm) of the cold-rolled steel sheet) and polished, and then a cross section of the polished specimen was subjected to nital etching and observed using a scanning electron microscope (SEM). At this time, after the nital etching, a structure having no irregularities on the specimen surface was determined to be ferrite, and a structure having a spherical or lamellar structure was determined to be cementite. Meanwhile, in the case of unrecrystallized ferrite containing a large number of dislocations, a crystal orientation difference occurs within grains. Therefore, after the crystal orientation of ferrite was measured using FESEM-EBSD, unrecrystallized ferrite in ferrite was distinguished by a kernel average misorientation (KAM) method, and the fraction thereof was measured.

[0129] In addition, a tensile test and a hole expansion test were performed to evaluate the properties of each cold-rolled steel sheet. The tensile test was performed using specimens taken in accordance with JIS No. 5 standard in a 0° direction with respect to the rolling direction of each cold-rolled steel sheet, and a relationship between tensile strength (TS) and elongation (EI) (corresponding to Relational Expression 1) and a yield ratio (YR) were calculated. The hole expansion test was performed by pressing and expanding a 10 mmØ punched hole (die inner diameter: 10.3 mm, clearance: 12.5%) at 20 mm/min using a conical punch having an apex angle of 60° in a direction in which a burr of the punched hole faced outward. Thereafter, a hole expansion ratio (HER) was obtained by the following equation.

$$\text{(Equation)} \quad \text{HER}(\%) = \{(D - D_0) / D_0\} \times 100$$

[0130] (D: hole diameter (mm) when a crack penetrated the sheet thickness, D₀: initial hole diameter (mm))

[0131] Meanwhile, in order to confirm contents (wt%) of specific elements (Cu, Cr, Ni, and Sn) at specific points in the thickness direction of the cold-rolled steel sheet, a cross section of each specimen was removed by FIB, and then the contents were measured by compositional analysis using FE-SEM. At this time, according to the definition of the surface layer portion, measurements were performed for the content in the surface layer portion and at a central portion (t/2) in the thickness direction, respectively. Measurements were repeated a total of 30 times at random points, respectively, and then the maximum value and the minimum value among the analyzed values of each element were removed, and the content was calculated as an average value.

[0132] In addition, in order to evaluate powdering properties, a 45-degree V-bending test was performed on plated steel sheets obtained by plating the respective cold-rolled steel sheets in a hot-dip galvanizing bath at 440 to 480°C. At this time, the test surface was disposed on the inner side of the bend, bending was performed at 60 degrees using a

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die having a tip radius of curvature of 1 mm, a tape was attached to the inner side and then removed, and powdering properties were evaluated on a 5-point scale with respect to the plating layer peeled off together with the tape. Specific evaluation criteria were set as follows, and a score of 2 points or higher was evaluated as passing.

- 5 Peeling width of less than 2 mm: 5 points
 Peeling width of 2 mm or more and less than 3 mm: 4 points
 Peeling width of 3 mm or more and less than 5 mm: 3 points
 Peeling width of 5 mm or more and less than 7 mm: 2 points
 Peeling width of 7 mm or more: 1 point

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[Table 1]

Steel type	Alloy composition (wt%)													(Ti+N b+V)
	C	Si	Mn	P	S	Al	N	Cu	Cr	Ni	Sn	One more of Ti, Nb, and V	Others	
A	0.014	0.02	0.18	0.003	0.002	0.023	0.0017	0.84	0.69	0.83	0.302	Ti 0.031	Hf 0.004	0.031
B	0.03 2	0.0 5	0.5 2	0.00 7	0.00 5	0.02 8	0.00 35	0.62	0.81	0.48	0.1 75	Ti 0.032 Nb 0.029	Y 0.005	0.061
C	0.06 5	0.0 6	0.6 3	0.01 5	0.00 9	0.03 5	0.00 46	0.45	0.36	0.42	0.0 82	Ti 0.049 V 0.035	W 0.03	0.084
D	0.071	0.08	0.95	0.028	0.012	0.033	0.0063	0.37	0.28	0.35	0.064	Ti 0.058 Nb 0.034 V 0.021	Mg 0.002	0.113
E	0.083	0.11	1.16	0.039	0.017	0.030	0.0081	0.24	0.23	0.24	0.0 43	Ti 0.086 Nb 0.055	Mo 0.03 Zr 0.02	0.141
F	0.12 6	0.3 2	1.3 8	0.04 6	0.02 1	0.03 4	0.00 97	0.13	0.11	0.14	0.0 15	Ti 0.092 Nb 0.056 V 0.037	B 0.0023 Sb 0.002	0.185
G	0.23 8	0.6 8	1.7 6	0.06 7	0.03 8	0.03 2	0.01 76	0.003	0.002	0.003	0.0 02	Ti 0.165 Nb 0.051	Ca 0.004 REM 0.001	0.216
XA	0.26 1	0.0 6	1.1 9	0.02 6	0.02 9	0.03 6	0.00 40	0.17	0.22	0.19	0.0 23	Ti 0.035 Nb 0.031	-	0.066
XB	0.08 1	0.7 3	1.0 5	0.02 3	0.02 4	0.03 4	0.00 54	0.25	0.23	0.20	0.0 21	Ti 0.047 V 0.034	-	0.081
XC	0.07 9	0.0 8	1.8 2	0.01 8	0.03 0	0.03 2	0.00 61	0.23	0.20	0.18	0.0 19	Ti 0.087	-	0.087
XD	0.08 3	0.0 6	1.1 2	0.01 7	0.03 2	0.72 1	0.00 68	0.24	0.19	0.21	0.0 18	Ti 0.064 Nb 0.029	-	0.093
XE	0.08 6	0.0 7	0.9 8	0.02 2	0.02 7	0.03 4	0.03 45	0.19	0.16	0.24	0.0 22	Ti 0.332 Nb 0.025 V 0.004	-	0.361
XF	0.07 8	0.1 2	1.0 4	0.01 8	0.02 5	0.03 3	0.00 54	1.15	0.20	0.22	0.0 25	Ti 0.049 V 0.032	-	0.081

(continued)

Steel type	Alloy composition (wt%)												(Ti+N b+V)	
	C	Si	Mn	P	S	Al	N	Cu	Cr	Ni	Sn	One more of Ti, Nb, and V		Others
XG	0.08 2	0.0 9	1.1 2	0.02 5	0.02 1	0.03 5	0.00 47	0.28	1.09	0.20	0.0 21	Ti 0.043 Nb 0.035	-	0.078
XH	0.08 0	0.0 7	1.1 7	0.02 3	0.01 8	0.03 2	0.00 42	0.30	0.23	1.23	0.0 26	Ti 0.036 Nb 0.032 V 0.002	-	0.070
XI	0.08 3	0.1 0	1.0 8	0.02 1	0.02 2	0.03 6	0.00 49	0.31	0.22	0.19	0.5 25	Ti 0.044 V 0.035	-	0.079
XJ	0.07 9	0.0 8	1.1 0	0.02 4	0.02 3	0.03 3	0.00 53	0.26	0.18	0.22	0.0 17	Ti 0.241 Nb 0.032	-	0.273
XK	0.08 1	0.0 6	1.1 2	0.02 2	0.02 0	0.03 1	0.00 51	0.23	0.21	0.19	0.0 12	Ti 0.046 V 0.236	-	0.282
XL	0.08 4	0.0 9	1.0 9	0.01 8	0.02 1	0.03 4	0.00 57	0.28	0.19	0.23	0.0 15	Ti 0.052 Nb 0.025 V 0.238	-	0.315

[Table 2]

Steel type	Reheating temperature (°C)	Finish rolling temperature (°C)	Coiling temperature (°C)	Cooling after coiling (°C/min)	Cold reduction ratio (%)	Heating rate (°C/s)	Annealing temperature (°C)	Annealing time (s)	Classification
A	1160	880	500	0.6	76	57	820	120	Inventive Example 1
B	1160	880	550	0.9	65	25	800	120	Inventive Example 2
B	1320	950	550	0.9	65	26	800	120	Comparative Example 1
B	880	630	320	0.2	65	24	790	120	Comparative Example 2
B	1280	950	770	9.5	65	31	790	120	Comparative Example 3
B	1050	820	550	0.9	28	32	800	120	Comparative Example 4
B	1160	880	550	0.8	65	32	580	120	Comparative Example 5
B	1160	880	550	0.9	65	29	960	120	Comparative Example 6
B	1160	880	550	0.9	65	28	800	5	Comparative Example 7
B	1160	880	550	1.0	65	27	800	1000	Comparative Example 8
B	1160	880	350	0.1	65	25	800	120	Comparative Example 9
B	1160	880	750	10.3	65	26	790	120	Comparative Example 10
B	1160	880	500	0.6	65	1	790	120	Comparative Example 11
B	1160	880	500	0.7	65	62	800	120	Comparative Example 12
C	1050	820	350	0.2	65	27	800	120	Inventive Example 3
D	1100	850	600	3.5	65	14	800	120	Inventive Example 4
E	1200	900	700	6.8	55	10	790	120	Inventive Example 5
F	1250	930	450	0.5	45	6	770	120	Inventive Example 6
G	1160	880	400	0.3	35	2	750	120	Inventive Example 7
XA	1160	880	500	0.7	65	21	800	120	Comparative Example 13
XB	1160	880	500	0.8	65	18	800	120	Comparative Example 14
XC	1160	880	500	0.6	65	19	800	120	Comparative Example 15
XD	1160	880	500	0.6	65	22	820	120	Comparative Example 16
XE	1160	880	500	0.7	65	25	820	120	Comparative Example 17
XF	1160	880	500	0.7	65	25	800	120	Comparative Example 18

(continued)

Steel type	Reheating temperature (°C)	Finish rolling temperature (°C)	Coiling temperature (°C)	Cooling after coiling (°C/min)	Cold reduction ratio (%)	Heating rate (°C/s)	Annealing temperature (°C)	Annealing time (s)	Classification
XG	1160	880	500	0.8	65	23	800	120	Comparative Example 19
XH	1160	880	500	0.8	65	21	800	120	Comparative Example 20
XI	1160	880	550	0.9	65	20	780	120	Comparative Example 21
XJ	1160	880	550	1.1	65	20	780	120	Comparative Example 22
XK	1160	880	550	1.0	65	17	800	120	Comparative Example 23
XL	1160	880	550	0.9	65	16	800	120	Comparative Example 24

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[Table 3]

5	Classification	A/B	Microstructure (area fraction%)		Mechanical properties			
			Ferrite	Cementite	YR	$TS^2 \times \sqrt{EI}$ (MPa ^{2%} 0.5)	$TS^2 \times \sqrt{HER}$ (MPa ^{2%} 0.5)	Powdering properties
	Inventive Example 1	0.18	98	2	0.54	0.65	0.93	5
10	Inventive Example 2	0.35	96	4	0.66	0.78	1.24	5
	Comparative Example 1	34.50	83	17	0.71	0.82	0.76	1
15	Comparative Example 2	0.13	86	14	0.68	0.77	0.98	1
	Comparative Example 3	32.10	81	19	0.69	0.79	0.83	1
20	Comparative Example 4	0.49	99	1	0.67	0.56	0.95	4
	Comparative Example 5	0.27	99	1	0.69	0.55	0.97	4
25	Comparative Example 6	31.40	73	27	0.97	2.33	3.82	1
	Comparative Example 7	0.29	97	3	0.64	0.57	0.94	3
30	Comparative Example 8	24.60	78	22	0.92	2.32	3.61	2
	Comparative Example 9	0.14	88	12	0.65	0.68	0.93	1
35	Comparative Example 10	27.50	83	17	0.69	0.65	0.87	3
	Comparative Example 11	0.18	96	4	0.71	0.56	0.92	3
40	Comparative Example 12	21.70	80	20	0.83	2.35	3.74	2
	Inventive Example 3	0.49	93	7	0.68	0.86	1.47	5
45	Inventive Example 4	0.37	89	11	0.72	0.93	1.75	5
	Inventive Example 5	0.58	85	15	0.79	1.54	2.28	5
50	Inventive Example 6	0.72	81	19	0.85	1.89	2.64	4
	Inventive Example 7	0.63	77	23	0.93	2.24	3.75	4
55	Comparative Example 13	17.20	84	16	0.72	0.75	1.03	2
	Comparative Example 14	25.40	81	19	0.70	0.72	1.14	3

(continued)

Classification	A/B	Microstructure (area fraction%)		Mechanical properties			
		Ferrite	Cementite	YR	$TS^2 \times \sqrt{EI}$ (MPa ^{2%} 0.5)	$TS^2 \times \sqrt{HER}$ (MPa ^{2%} 0.5)	Powdering properties
Comparative Example 15	23.70	87	13	0.69	0.81	0.96	2
Comparative Example 16	21.40	90	10	0.75	0.86	0.93	3
Comparative Example 17	20.50	85	15	0.73	0.82	0.97	3
Comparative Example 18	23.60	87	13	0.69	0.78	1.20	2
Comparative Example 19	26.40	84	16	0.67	0.81	1.28	2
Comparative Example 20	16.80	88	12	0.70	0.79	1.34	2
Comparative Example 21	17.90	85	15	0.72	0.76	1.25	3
Comparative Example 22	15.80	80	20	0.98	0.55	0.78	2
Comparative Example 23	19.50	83	17	0.97	0.52	0.79	2
Comparative Example 24	21.40	86	14	0.96	0.56	0.82	3
In Table 3, A/B means a value (A/B) obtained by dividing an average content of (Cu+Cr+Ni+Sn) in a surface layer portion (wt%, A) by an average content of (Cu+Cr+Ni+Sn) in a central portion (wt%, B).							

[0133] As shown in Tables 1 to 3, in Inventive Examples 1 to 7 satisfying both the alloy composition and manufacturing conditions according to an embodiment in the present disclosure, the microstructure included ferrite as a main phase with cementite appropriately formed, and thus strength and hole expansion ratio were excellent. In addition, powdering properties after plating were also excellent.

[0134] On the other hand, in Comparative Examples 1 to 24 not satisfying one or more of the alloy composition and manufacturing conditions according to an embodiment in the present disclosure, the microstructure was not formed as intended, or specific elements were non-uniformly distributed, and thus at least one property, such as strength, hole expansion ratio, and powdering properties (plating adhesion), was inferior.

[0135] As described above, the present disclosure has technical significance in that excellent hole expansion ratio and plating adhesion may be simultaneously achieved.

Claims

1. A cold-rolled steel sheet comprising, by wt%, greater than 0% to 0.2500% of carbon (C), greater than 0% to 0.700% of silicon (Si), greater than 0% to 1.800% of manganese (Mn), greater than 0% to 0.700% of aluminum (Al), 0.080% or less of phosphorus (P), 0.050% or less of sulfur (S), 0.0300% or less of nitrogen (N), 1.000% or less of copper (Cu), 1.000% or less of nickel (Ni), 1.000% or less of chromium (Cr),

one or more selected from 0.050% or less of magnesium (Mg), 0.050% or less of calcium (Ca), 0.050% or less of rare earth elements (REM) excluding yttrium (Y), 0.50% or less of tungsten (W), 0.50% or less of zirconium (Zr), 0.500% or less of antimony (Sb), 0.500% or less of tin (Sn), 0.500% or less of cobalt (Co), 0.200% or less of yttrium (Y), and 0.200% or less of hafnium (Hf),

one or more selected from 0.220% or less of titanium (Ti), 0.220% or less of niobium (Nb), 0.220% or less of

vanadium (V), 1.000% or less of molybdenum (Mo), and 0.0200% or less of boron (B), and the balance of Fe and inevitable impurities,

wherein A/B satisfies 0.15 to 30.00, where A represents an average content (wt%) of (Cu+Cr+Ni+Sn) in a surface layer portion, and B represents an average content (wt%) of (Cu+Cr+Ni+Sn) in a central portion, (where the central portion refers to a point t/2 in a thickness direction, and the surface layer portion refers to a region extending from a surface to a point at which concentrations change when concentrations of Cu, Cr, Ni, and Sn are measured in the thickness direction, the surface layer portion extending to a point corresponding to 99% of a content of (Cu+Cr+Ni+Sn) in the central portion in the measured concentration values when a content of (Cu+Cr+Ni+Sn) at the surface is greater than the content in the central portion, or extending to a point corresponding to 1% of the content of (Cu+Cr+Ni+Sn) in the central portion in the measured concentration values when the content of (Cu+Cr+Ni+Sn) at the surface is less than the content of (Cu+Cr+Ni+Sn) in the central portion).

2. The cold-rolled steel sheet of claim 1, wherein, when one or more of titanium (Ti), niobium (Nb), and vanadium (V) are added, a total content of Ti, Nb, and V (Ti+Nb+V) is 0.220% or less.
3. The cold-rolled steel sheet of claim 1, wherein a microstructure of the cold-rolled steel sheet includes ferrite in an area fraction of 75 to 98% and the balance of cementite.
4. The cold-rolled steel sheet of claim 1, wherein a relationship between tensile strength (TS) and elongation (El) of the cold-rolled steel sheet satisfies the following Relational Expression 1:

[Relational Expression 1]

$$0.6 \times 10^6 \leq TS^2 \times \sqrt{El} \leq 2.3 \times 10^6$$

(the unit of Relational Expression 1 is (MPa)^{2%}0.5).

5. The cold-rolled steel sheet of claim 1, wherein a relationship between tensile strength (TS) and hole expansion ratio (HER) of the cold-rolled steel sheet satisfies the following Relational Expression 2:

[Relational Expression 2]

$$0.9 \times 10^6 \leq TS^2 \times \sqrt{HER} \leq 3.8 \times 10^6$$

(the unit of Relational Expression 2 is (MPa)^{2%}0.5).

6. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a yield ratio of 0.50 to 0.95.
7. A method for manufacturing a cold-rolled steel sheet, the method comprising:

preparing a steel slab containing, by wt%, greater than 0% to 0.2500% of carbon (C), greater than 0% to 0.700% of silicon (Si), greater than 0% to 1.800% of manganese (Mn), greater than 0% to 0.700% of aluminum (Al), 0.080% or less of phosphorus (P), 0.050% or less of sulfur (S), 0.0300% or less of nitrogen (N), 1.000% or less of copper (Cu), 1.000% or less of nickel (Ni), 1.000% or less of chromium (Cr), one or more selected from 0.050% or less of magnesium (Mg), 0.050% or less of calcium (Ca), 0.050% or less of rare earth elements (REM) excluding yttrium (Y), 0.50% or less of tungsten (W), 0.50% or less of zirconium (Zr), 0.500% or less of antimony (Sb), 0.500% or less of tin (Sn), 0.500% or less of cobalt (Co), 0.200% or less of yttrium (Y), and 0.200% or less of hafnium (Hf), one or more selected from 0.220% or less of titanium (Ti), 0.220% or less of niobium (Nb), 0.220% or less of vanadium (V), 1.000% or less of molybdenum (Mo), and 0.0200% or less of boron (B), and the balance of Fe and inevitable impurities;

heating the steel slab in a temperature range of 900 to 1,300°C;

finish-rolling the heated steel slab in an austenite region at a temperature equal to or higher than an Ar3 transformation point or in a ferrite region at a temperature equal to or lower than the Ar3 transformation point to obtain a hot-rolled steel sheet;

coiling the hot-rolled steel sheet in a temperature range of 330 to 750°C;

cooling the coiled hot-rolled steel sheet at a rate of 0.2 to 10°C/min to a temperature range of 250 to 300°C;
cold-rolling the hot-rolled steel sheet after the cooling at a cold reduction ratio of 30 to 90% to obtain a cold-
rolled steel sheet; and
annealing the cold-rolled steel sheet at 600°C or higher for 10 seconds or longer.

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8. The method of claim 7, 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.
9. The method of claim 7, wherein, when one or more of titanium (Ti), niobium (Nb), and vanadium (V) are added to
10 the steel slab, a total content of Ti, Nb, and V (Ti+Nb+V) is 0.220% or less.
10. A plated steel sheet comprising the cold-rolled steel sheet of any one of claims 1 to 6 and a zinc-based plating layer formed on at least one surface of the cold-rolled steel sheet.
- 15 11. The plated steel sheet of claim 10, wherein the plating layer has a powdering peeling width of less than 7 mm.
12. A method for manufacturing a plated steel sheet, the method comprising plating the cold-rolled steel sheet of any one of claims 1 to 6 to obtain a plated steel sheet,
wherein the plating is a hot-dip plating or electroplating process.
- 20 13. The method of claim 12, wherein the hot-dip plating includes hot-dip galvanizing performed in a temperature range of 440 to 520°C, and
the method optionally further comprises performing alloying heat treatment after the hot-dip galvanizing.
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020420

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i; C22C 38/06(2006.01)i; C22C 38/60(2006.01)i; C22C 38/42(2006.01)i; C22C 38/44(2006.01)i;
C22C 38/00(2006.01)i; C22C 38/52(2006.01)i; C22C 38/50(2006.01)i; C22C 38/48(2006.01)i; C22C 38/46(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 38/58(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C21D 9/56(2006.01); C22C 38/00(2006.01);
C22C 38/12(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: 냉연강판(cold rolled steel sheet), 페라이트(ferrite), 세멘타이트(cementite), 구리
(copper), 니켈(nickel), 크롬(chromium), 티타늄(titanium), 가열(heating), 냉각(cooling)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	KR 10-1830527 B1 (POSCO) 21 February 2018 (2018-02-21) See paragraphs [0094]-[0095] and claims 1 and 5.	1-13
A	JP 2007-016319 A (SUMITOMO METAL IND. LTD.) 25 January 2007 (2007-01-25) See paragraphs [0066]-[0067] and claims 1-4.	1-13
A	CN 107923013 A (JFE STEEL CORP.) 17 April 2018 (2018-04-17) See claims 1-7.	1-13
A	JP 2014-025132 A (NIPPON STEEL & SUMITOMO METAL) 06 February 2014 (2014-02-06) See paragraphs [0033]-[0034] and claims 1 and 3.	1-13

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

* Special categories of cited documents:

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“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

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020420

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