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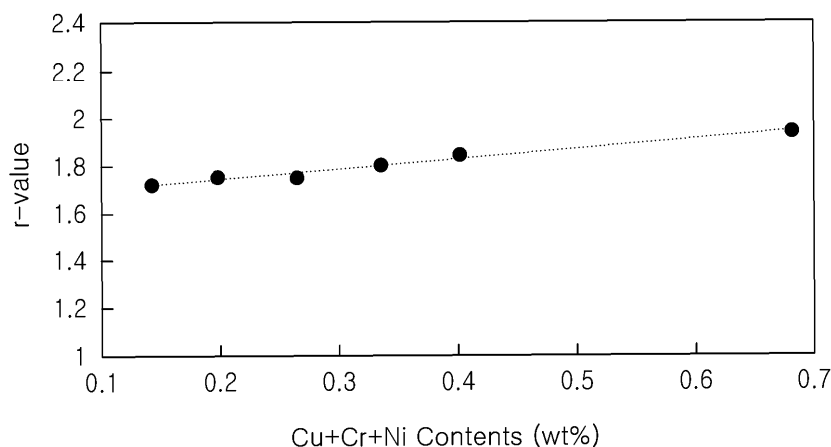
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(54) **COLD-ROLLED STEEL SHEET AND MANUFACTURING METHOD THEREOF**

(57) The present invention relates to a cold-rolled steel sheet and a manufacturing method thereof and, more specifically, to a cold-rolled steel sheet having

both excellent strength and formability, and a manufacturing method thereof.

[FIG. 1]



Description

Technical Field

5 **[0001]** The present disclosure relates to a cold-rolled steel sheet and a manufacturing method thereof, and more specifically, to a cold-rolled steel sheet having both excellent strength and formability and a manufacturing method thereof.

Background Art

10 **[0002]** In order to address the global climate crisis, automakers are asking steel companies to supply automobile steel sheets with a gradual reduction in CO₂ emissions, aiming to achieve carbon neutrality by 2050. For this reason, recently, steel companies have developed automobile steel sheets with reduced CO₂ emissions through steel scrap recycling using a blast furnace-basic oxygen furnace steelmaking method or an electric arc furnace steelmaking method.

15 **[0003]** When steel scrap is used as a raw material, it may be difficult to remove remaining elements (tramp elements) such as Cu, Cr, Ni, or the like included in the steel scrap during refining, and may be included in steel after the refining. The remaining elements have problems that deteriorate properties or surface quality of the steel, so high-quality thin plate products represented by automobile steel sheets so far use molten iron as a main raw material, and may be manufactured by extremely controlling inclusion of the remaining elements while greatly reducing C and N in the steel in a general blast furnace- converter process.

[0004] Meanwhile, a technology for manufacturing an automobile steel sheet with excellent processability from electric arc furnace steel including remaining elements using an electric arc furnace steelmaking method was proposed as follows.

25 **[0005]** Patent Documents 1 and 2 present a technology for manufacturing a cold-rolled steel sheet having excellent processability. Specifically, Patent Documents 1 and 2 disclose a cold-rolled steel sheet having excellent cold processability even though a large amount of remaining elements may be included.

[0006] However, the technologies limit incorporation of Cu and Ni as remaining elements because formability deteriorates due to a decrease in the Lankford value (r-value) according to the remaining elements of the steel sheet.

30 **[0007]** Although a technology for manufacturing automobile steel sheets including remaining elements has been proposed, automobile steel sheets with improved strength and formability despite including remaining elements have not been developed.

[0008] (Patent Document 1) Japanese Patent Publication No. 1995-118795

[0009] (Patent Document 2) Japanese Patent Publication No. 1998-025541

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Disclosure of Invention

Technical Problem

40 **[0010]** An embodiment of the present disclosure is to provide a cold-rolled steel sheet and a manufacturing method thereof.

[0011] An embodiment of the present disclosure is to provide a cold-rolled steel sheet having both excellent strength and formability and a manufacturing method thereof, in manufacturing the steel sheet using a steel scrap raw material.

45 **[0012]** An object of the present disclosure is not limited to the description. One of ordinary skill in the art will have no difficulty in understanding an additional object of the present disclosure from the overall content of the present specification.

Solution to Problem

50 **[0013]** An embodiment of the present disclosure provides a cold-rolled steel sheet comprising, by weight, C: 0.0500% or less, Si: 0.005% to 0.080%, Mn: 0.500% or less, Al: 0.0800% or less, P: 0.0800% or less, S: 0.0500% or less, N: 0.0300% or less, Ti: 0.001% to 0.050%, Nb: 0.001% to 0.050%, Cu: 1.000% or less, Ni: 1.000% or less, Cr: 1.000% or less, at least one of Sb or Sn: 0.500% or less, a remainder of Fe, and unavoidable impurities,

55 wherein a T value defined in Relationship 1 below is 0.90 to 1.20, and
wherein a tensile strength is 330 MPa or more:

[Relationship 1]

$$T = R / (0.4 ([Cu] + [Cr] + [Ni]) + 1.6)$$

(In the Relationship, R is an r-value, and [Cu], [Cr], and [Ni] are a weight percent of an element corresponding thereto, respectively.)

[0014] The cold-rolled steel sheet may further comprise, by weight, Mo: 1% or less and B: 0.02% or less.

[0015] Cu+Cr+Ni of the cold-rolled steel sheet may be 0.7% or less, by weight.

[0016] An A value defined in Relationship 2 below in the cold-rolled steel sheet may be 0.40 to 1.40:

[Relationship 2]

$$A = [Mn] / 10 ([Ti] + [Nb])$$

(In the Relationship, [Mn], [Ti], and [Nb] are a weight percent of an element corresponding thereto, respectively.)

[0017] A microstructure of the cold-rolled steel sheet may include, by area, 95% or more ferrite and a remaining structure.

[0018] An average grain size of ferrite in the cold-rolled steel sheet may be 13.0 μm or less.

[0019] The cold-rolled steel sheet may have a tensile strength of 330 to 420 MPa and an elongation of 32% or more.

[0020] The cold-rolled steel sheet may have an r-value of 1.60 or more.

[0021] An embodiment of the present disclosure provides a method of manufacturing a cold-rolled steel sheet, comprising reheating a steel slab including, by weight, C: 0.0500% or less, Si: 0.005% to 0.080%, Mn: 0.500% or less, Al: 0.0800% or less, P: 0.0800% or less, S: 0.0500% or less, N: 0.0300% or less, Ti: 0.001% to 0.050%, Nb: 0.001% to 0.050%, Cu: 1.000% or less, Ni: 1.000% or less, Cr: 1.000% or less, at least one of Sb or Sn: 0.500% or less, a remainder of Fe, and unavoidable impurities,

hot-rolling the reheated steel slab;
coiling the hot-rolled steel sheet;
cold-rolling the coiled steel sheet; and
annealing the cold-rolled steel sheet.

[0022] The steel slab may further comprise, by weight, Mo: 1% or less and B: 0.02% or less.

[0023] Cu+Cr+Ni of the steel slab may be 0.7% or less, by weight.

[0024] An A value defined in Relationship 2 below in the steel slab may be 0.40 to 1.40:

[Relationship 2]

$$A = [Mn] / 10 ([Ti] + [Nb])$$

(In the Relationship, [Mn], [Ti], and [Nb] are a weight percent of an element corresponding thereto, respectively.)

[0025] The reheating may be performed in a temperature range of 900 to 1300°C,

the hot-rolling may be performed at a finishing temperature of 880°C or higher,
the coiling may be performed in a temperature range of 500 to 800°C,
the cold-rolling may be performed at a cold-roll pressing rate of 50 to 90%, and
the annealing may be performed in a temperature range of 600°C or higher for 10 seconds or more.

Advantageous Effects of Invention

[0026] According to an embodiment of the present disclosure, a cold-rolled steel sheet and a manufacturing method thereof may be provided.

[0027] According to an embodiment of the present disclosure, a cold-rolled steel sheet having both excellent

strength and formability and a manufacturing method thereof may be provided.

[0028] According to an embodiment of the present disclosure, a high strength, high formability cold-rolled steel sheet that may be used for various purposes, including automobile components, and a manufacturing method thereof, may be provided.

[0029] Various advantages and effects of the present disclosure are not limited to the description, and can be more easily understood in the process of explaining the specific embodiment of the present disclosure.

Brief Description of Drawings

[0030] FIG. 1 graphically illustrates an r-value according to a sum of Cu, Cr, and Ni contents.

Best Mode for the Invention

[0031] Hereinafter, preferred embodiments of the present disclosure will be described. The embodiments of the present disclosure may be modified in various forms, and the scope of the present disclosure should not be construed as being limited to the embodiments described below. The present embodiments may be provided to explain the present disclosure in more detail to those skilled in the art to which the present disclosure pertains.

[0032] Hereinafter, the present disclosure will be described in detail.

[0033] Hereinafter, a steel composition of the present disclosure will be described in detail.

[0034] Unless otherwise stated in the present disclosure, % indicating the content of each element may be based on weight.

[0035] A cold-rolled steel sheet according to an embodiment of the present disclosure may include, by weight, C: 0.0500% or less, Si: 0.005% to 0.080%, Mn: 0.500% or less, Al: 0.0800% or less, P: 0.0800% or less, S: 0.0500% or less, N: 0.0300% or less, Ti: 0.001% to 0.050%, Nb: 0.001% to 0.050%, Cu: 1.000% or less, Ni: 1.000% or less, Cr: 1.000% or less, and at least one of Sb or Sn: 0.500% or less.

Carbon (C): 0.0500% or less

[0036] Carbon (C) may be an important element in the present disclosure, and when the content exceeds 0.0500%, it may be difficult to secure elongation and an r-value required by a steel sheet. According to an embodiment of the present disclosure, the content may be 0.0400% or less. Meanwhile, although a lower limit of the content is not particularly limited, when the content may be less than 0.0003%, there may be little effect of reducing carbon (C) and there may be a concern about an increase in steelmaking costs. According to an embodiment of the present disclosure, the content of carbon (C) may be 0.0003% or more.

Silicon (Si): 0.005% to 0.080%

[0037] Silicon (Si) may be an element that has an effect of improving strength by strengthening a solid solution, and may be an element that strengthens ferrite, uniformizes structure, and improves workability. It may be also an element necessary for deoxidation during steelmaking. When the content of silicon (Si) exceeds 0.080%, plating defect problems such as unplated plating and weldability of a steel sheet may be deteriorated in the plating process. According to an embodiment of the present disclosure, it may be 0.070% or less. On the other hand, when the content is less than 0.005%, there may be little effect of reducing silicon (Si) and there may be a concern of an increase in manufacturing cost.

Manganese (Mn): 0.001% to 0.500%

[0038] Manganese (Mn) may be a useful element for increasing strength and ductility together. In particular, it may be known as a solid solution reinforcing element that precipitates S dissolved in steel with MnS to prevent hot shortness by a solid solution S. When the manganese (Mn) content exceeds 0.500%, workability may be deteriorated. According to an embodiment of the present disclosure, it may be 0.400% or less. On the other hand, when the content is less than 0.001%, there may be little effect of reducing manganese (Mn) and there may be a concern about an increase in manufacturing cost. According to an embodiment of the present disclosure, manganese (Mn) may be 0.010% or more. According to an embodiment of the present disclosure, manganese (Mn) may be 0.100% or more. According to an embodiment of the present disclosure, manganese (Mn) may be 0.150% or more.

Aluminum (Al): 0.0800% or less

[0039] Aluminum (Al) may be an element that combines with oxygen in steel to perform deoxidation. In addition, like Si, it may be an element that strengthens ferrite, uniformizes the structure, and improves workability. When the aluminum (Al) content exceeds 0.0800%, workability may be deteriorated. According to an embodiment of the present disclosure, it may be 0.0600% or less. Although a lower limit of the aluminum (Al) content is not particularly limited, when the content is less than 0.0010%, there may be little effect of reducing aluminum (Al) and there may be a concern of an increase in manufacturing costs. According to an embodiment of the present disclosure, the content may be 0.0010% or more.

Phosphorus (P): 0.0800% or less

[0040] Phosphorus (P) may be an element used to increase strength. When the content exceeds 0.0800%, workability and brittleness may be deteriorated. According to an embodiment of the present disclosure, an upper limit of the phosphorus (P) content may be 0.0700% or less. Meanwhile, although the lower limit of the phosphorus (P) content is not particularly limited, when it is less than 0.0010%, there may be little effect of reducing phosphorus (P) and there may be a concern about an increase in manufacturing cost. According to an embodiment of the present disclosure, it may be 0.0010% or more.

Sulfur (S): 0.0500% or less

[0041] Sulfur (S) may be an element that makes MnS in a steel sheet and deteriorates ductility because it may be included as an impurity. According to an embodiment of the present disclosure, an upper limit of the sulfur (S) content may be limited to 0.0500%. According to an embodiment of the present disclosure, it may be 0.0400% or less. Meanwhile, although a lower limit of the sulfur (S) content is not particularly limited, when it is less than 0.0010%, there may be little effect of reducing sulfur (S) and there may be a concern that the manufacturing cost may increase. According to an embodiment of the present disclosure, it may be 0.0010% or more.

Nitrogen (N): 0.0300% or less

[0042] Nitrogen (N) may be an element that contains an impurity and forms a nitride in a continuous casting to cause a crack in a slab. According to an embodiment of the present disclosure, an upper limit of the nitrogen (N) content may be limited to 0.0300%. According to an embodiment of the present disclosure, an upper limit of the nitrogen (N) content may be 0.0200% or less. On the other hand, although a lower limit of the nitrogen (N) content is not particularly limited, when it is less than 0.0010%, there may be little effect of reducing nitrogen (N) and there may be a concern about an increase in manufacturing cost. According to an embodiment of the present disclosure, it may be 0.0010% or more.

Titanium (Ti): 0.001% to 0.050%

[0043] Titanium (Ti) may be an important element that forms a precipitate of a steel sheet. It may be included to improve strength and impact toughness of the steel sheet. The titanium (Ti) may be an element capable of preventing deterioration of workability due to solid solution C and N by precipitating the solid solution C and N in steel as a carbide or a nitride. In order to secure the above-described effects, in the present disclosure, 0.001% or more may be included. When the content is less than 0.001%, there may be little effect of the addition of titanium (Ti). Meanwhile, according to an embodiment of the present disclosure, an upper limit of the titanium (Ti) content may be limited to 0.050%. According to an embodiment of the present disclosure, it may be 0.040% or less.

Niobium (Nb): 0.001% to 0.050%

[0044] Niobium (Nb) may be an important element that forms a precipitate of a steel sheet. It may be included to improve strength and impact toughness of the steel sheet. The niobium (Nb) may be an element capable of precipitating solid solution C and N in steel as a carbide or a nitride to prevent deterioration of workability due to solid solution C and N. In order to secure the above-described effects, the present disclosure may contain 0.001% or more. When the content is less than 0.001%, there may be little effect of the addition of niobium (Nb). Meanwhile, according to an embodiment of the present disclosure, an upper limit of the niobium (Nb) content may be limited to 0.050%. According to an embodiment of the present disclosure, it may be 0.040% or less.

Copper (Cu): 1.000% or less, nickel (Ni): 1.000% or less

[0045] Copper (Cu) and nickel (Ni) may be elements that stabilize austenite and suppress corrosion. In addition, copper (Cu) and nickel (Ni) may have an effect of suppressing delayed hydrogen destruction by preventing hydrogen from penetrating into a steel sheet by being concentrated on a surface of the steel sheet and moving into the steel sheet. In addition, when the content of copper (Cu) and nickel (Ni) is 1.000% or less, deterioration of workability may be suppressed. According to an embodiment of the present disclosure, a lower limit of each of copper (Cu) and nickel (Ni) is not particularly limited, but when the content is less than 0.010%, there may be little effect on the addition of copper (Cu) and nickel (Ni). According to an embodiment of the present disclosure, each of copper (Cu) and nickel (Ni) may include 0.010% or more.

Chromium (Cr): 1.000% or less

[0046] Chromium (Cr) may be an element that suppresses austenite decomposition during alloying treatment and stabilizes austenite like Mn. In addition, when the content of chromium (Cr) is 1.000% or less, deterioration of workability may be suppressed. According to an embodiment of the present disclosure, it may be 0.900% or less. Meanwhile, a lower limit of the chromium (Cr) content is not particularly limited, but when the content is less than 0.010%, there may be little effect on addition of chromium (Cr). According to an embodiment of the present disclosure, 0.010% or more of chromium (Cr) may be included.

At least one of antimony (Sb) or tin (Sn): 0.500% or less

[0047] Antimony (Sb) and tin (Sn) may be elements that improve plating wettability and plating adhesion of a steel sheet. When the sum of the contents of at least one of antimony (Sb) and tin (Sn) exceeds 0.500%, brittleness of the steel sheet increases, and thus cracks may occur during hot or cold processing. In addition, when the sum of the contents of antimony (Sb) and tin (Sn) is 0.500% or less, deterioration of workability may be suppressed. According to an embodiment of the present disclosure, it may be 0.400% or less. Meanwhile, a lower limit of the contents of antimony (Sb) and tin (Sn) is not particularly limited, but when the contents is less than 0.0005%, there may be little effect on addition of antimony (Sb) and tin (Sn). According to an embodiment of the present disclosure, at least one of antimony (Sb) or tin (Sn) may be 0.0005% or more.

[0048] A steel material of the present disclosure may include remaining iron (Fe) and inevitable impurities, in addition to the above-described composition. Since inevitable impurities may be unintentionally mixed in a conventional manufacturing process, it cannot be excluded. Since these impurities may be known to anyone skilled in the art in steel manufacturing, all of the contents may not be specifically mentioned in the specification.

[0049] A cold-rolled steel sheet according to an embodiment of the present disclosure may further include, by weight, Mo: 1% or less and B: 0.02% or less.

Molybdenum (Mo): 1.0% or less

[0050] Molybdenum (Mo) may be an element that inhibits austenite decomposition during alloying treatment and stabilizes austenite like Mn. Also, when the content of molybdenum (Mo) is 1.0% or less, deterioration of workability may be suppressed. According to an embodiment of the present disclosure, it may be 0.9% or less. Meanwhile, a lower limit of the molybdenum (Mo) content is not particularly limited, but when the content is less than 0.01%, there may be little effect on the addition of molybdenum (Mo). According to an embodiment of the present disclosure, the molybdenum (Mo) may be 0.01 % or more.

Boron (B): 0.02% or less

[0051] Boron (B) may be an element that enhances strength by improving quenching properties and suppresses nucleation of a grain boundary. When the content of boron (B) exceeds 0.02%, deep-drawing properties of the steel sheet may be deteriorated. According to an embodiment of the present disclosure, it may be 0.01% or less. Meanwhile, a lower limit of the boron (B) content is not particularly limited, but when the content is less than 0.0001%, there may be little effect on the addition of boron (B). According to an embodiment of the present disclosure, boron (B) may be 0.0001% or more.

[0052] According to an embodiment of the present disclosure, Cu+Cr+Ni of the cold-rolled steel sheet may be 0.7% or less, by weight.

[0053] According to an embodiment of the present disclosure, Cu, Cr, and Ni may be included in the steel sheet by using a steel scrap as a material in manufacturing of the steel sheet, and the sum of contents thereof may be 0.7% or

less. A lower limit of the sum of Cu, Cr, and Ni contents is not particularly limited, but may be included in an amount of 0.003% or more.

[0054] The cold-rolled steel sheet according to an embodiment of the present disclosure may have an A value defined in the following Relationship 2 of 0.40 to 1.40.

[Relationship 2]

$$A = [\text{Mn}] / 10 ([\text{Ti}] + [\text{Nb}])$$

(In the Relationship, [Mn], [Ti], and [Nb] are a weight percent of an element corresponding thereto, respectively.)

[0055] In accordance with an embodiment of the present disclosure, even when large amounts of Cu, Cr, and Ni are included, formability may be ensured by more strictly controlling an alloy composition through the Relationship 2.

[0056] When an A value defined in Relationship 2 is less than 0.40, or the value thereof exceeds 1.40, desired strength and formability may not be properly ensured.

[0057] Hereinafter, a steel microstructure of the present disclosure will be described in detail.

[0058] Unless otherwise stated in the present disclosure, a percentage indicating a fraction of microstructure may be based on an area.

[0059] A microstructure of the cold-rolled steel sheet according to an embodiment of the present disclosure may be an area%, and may include 95% or more of ferrite and a remaining structure.

[0060] According to an embodiment of the present disclosure, 95% or more of ferrite may be included to secure formability. When the fraction is less than 95%, there may be a problem that formability may be rapidly deteriorated.

[0061] A remaining tissue other than ferrite may include a low-temperature transformation phase, and according to an embodiment of the present disclosure, the low-temperature transformation phase may include martensite, bainite, or the like. According to an embodiment of the present disclosure, ferrite may be 100%.

[0062] A cold-rolled steel sheet according to an embodiment of the present disclosure may have an average ferrite grain size of 13.0 μm or less.

[0063] When the average ferrite grain size exceeds 13.0 μm, it may be difficult to secure desired strength of the present disclosure. According to an embodiment of the present disclosure, it may be 12.5 μm or less. Although not particularly limited to a lower limit of the average ferrite grain size, according to an embodiment of the present disclosure, it may be 6.5 μm or more.

[0064] A cold-rolled steel sheet according to an embodiment of the present disclosure may have a T value defined in the following Relationship 1 of 0.90 to 1.20.

[Relationship 1]

$$T = R / (0.4 ([\text{Cu}] + [\text{Cr}] + [\text{Ni}]) + 1.6)$$

(In the Relationship, R is an r-value, and [Cu], [Cr], and [Ni] are a weight percent of an element corresponding thereto, respectively.)

[0065] According to an embodiment of the present disclosure, even when large amounts of Cu, Cr, and Ni are included, a desired r-value may be secured. According to an embodiment of the present disclosure, as the sum of the contents of Cu, Cr, and Ni increases, the r-value may increase.

[0066] The Relationship 1 may indicate a relationship between Cu, Cr, and Ni contents and an r-value. In accordance with an embodiment of the present disclosure, as the sum of the Cu, Cr, and Ni contents increases, the r-value may increase, so that a ratio thereof defined in Relationship 1 may be ensured within a certain range.

[0067] When the T value defined in Relationship 1 is less than 0.90, or exceeds 1.20, the r-value may not be sufficiently ensured while satisfying the desired strength.

[0068] A cold-rolled steel sheet according to an embodiment of the present disclosure may have a tensile strength of 330 to 420 MPa, an elongation of 32% or more, a product (TSxEl) of the tensile strength and the elongation of 12.0 to 16.0 GPa·%, and an r-value (Lankford value) of 1.60 or more.

[0069] According to an embodiment of the present disclosure, the tensile strength may be 340 MPa or more. According to an embodiment of the present disclosure, the tensile strength may be 410 MPa or less.

[0070] Hereinafter, a steel manufacturing method of the present disclosure will be described in detail.

[0071] According to an embodiment of the present disclosure, the cold-rolled steel sheet may be manufactured by reheating, hot-rolling, coiling, cold-rolling, and annealing a steel slab satisfying an alloy composition.

Reheating

[0072] A steel slab satisfying an alloy composition according to an embodiment of the present disclosure may be reheated in a temperature range of 900 to 1300°C.

[0073] When a reheating temperature is less than 900°C, a rolling load increases during hot-rolling, thereby lowering stability of hot-rolling. According to an embodiment of the present disclosure, the reheating temperature may be 1100°C or higher. On the other hand, when the reheating temperature exceeds 1300°C, workability and plating adhesion may be inferior, and a melting point of steel may be reached and melted. According to an embodiment of the present disclosure, the reheating temperature may be 1160°C or less.

[0074] According to an embodiment of the present disclosure, conditions of a solvent process for manufacturing a steel slab or steel ingot is not particularly limited.

[0075] According to an embodiment of the present disclosure, the steel slab or steel ingot may be manufactured by an electric furnace or new furnace-electric furnace process, and pig iron may be used together with a steel scrap as a raw material used in the electric furnace or furnace-electric furnace process. In this case, pig iron means molten iron obtained in the furnace-electric furnace process, corrugate, hot briquette iron (HBI), or the like.

[0076] In the electric furnace, desulfurization treatment may be performed by ladle refining after exiting the electric furnace, and vacuum degassing treatment of desulfurization and post-processing may be performed. In addition, steel obtained in the electric furnace may be adjusted to become a final desired alloy component by adding an alloy component while performing the degassing treatment. In this case, an RH method and a DH method may be general as a vacuum degassing treatment method, but oxygen injection into the degassing tank may be performed in parallel. For oxygen injection, there may be an oxygen injection method using a degassing lance.

[0077] According to an embodiment of the present disclosure, although the casting method is not particularly limited, continuous casting may be performed to improve productivity.

Hot-rolling

[0078] The reheated steel slab may be hot-rolled to a finishing temperature of 880°C or higher.

[0079] During hot-rolling, when the finishing temperature is less than 880°C, there may be a concern that abnormal rolling may be performed, causing tissue non-uniformity. According to an embodiment of the present disclosure, during the hot-rolling process, conditions is not particularly limited, and conventional conditions applied in the same technical field may be applied.

Coiling

[0080] The hot-rolled steel sheet may be coiled in a temperature range of 500 to 800°C.

[0081] In order to improve high strength and high performance formation of the steel sheet, the coiling temperature may be limited to 500°C or higher. According to an embodiment of the present disclosure, the coiling temperature may be 600°C or higher. On the other hand, when the coiling temperature exceeds 800°C, it may cause a problem that too thick a scale may be formed on a surface of the hot-rolled coil.

Cold-rolling

[0082] The coiled steel sheet may be cold-rolled at a cold-rolling rate of 50 to 90%.

[0083] In order to improve workability of the steel sheet, a cold-rolling rate may be 50% or more. When the cold-rolling rate is less than 50%, it may be difficult to secure a target thickness, and it may be difficult to correct a shape of the steel sheet. In the present disclosure, an upper limit of the cold-roll pressing rate is not particularly limited, but when an upper limit is too excessive, a cold-roll pressing load may be caused, and thus it may be limited to 90% or less in consideration thereof.

Annealing

[0084] The cold-rolled steel sheet may be annealed for 10 seconds or more in a temperature range of 600°C or higher.

[0085] According to an embodiment of the present disclosure, annealing process conditions may be performed under normal conditions, and may be performed by a box-type annealing method or continuous annealing method.

[0086] When the annealing temperature is less than 600°C or the time is less than 10 seconds, recrystallization may not be sufficiently performed, and thus excellent processability may not be ensured. According to an embodiment of the present disclosure, it may be performed at 800°C or higher. In the present disclosure, an upper limit of the

temperature and time during the annealing is not particularly limited, but 960°C and 15 minutes may be limited to an upper limit, respectively, in consideration of the concern of facility problems due to high-temperature annealing and the deterioration of powderability.

[0087] According to an embodiment of the present disclosure, after annealing, a surface treatment process may be additionally performed as necessary. The surface treatment process may include galvanizing, tin plating, enamel, or the like.

[0088] In addition, according to an embodiment of the present disclosure, when necessary, special treatment may be performed to improve chemical conversion treatment, weldability, press formability, corrosion resistance, or the like.

[0089] Hereinafter, the present disclosure will be described in more detail through embodiments. However, it may be important to note that the following embodiments may be intended to illustrate the present disclosure in more detail, and may not be intended to limit the scope of the present disclosure.

Mode for the Invention

[0090] After preparing a steel slab having an alloy composition of the following Table 1, a cold-rolled steel sheet was manufactured according to conditions shown in the following Table 2. The steel slab was obtained through the following process. First, after an steel scrap mixed with a molten iron of an existing blast furnace was introduced into an electric furnace to obtain molten steel, the molten steel was transferred to a ladle to perform vacuum degassing in a RH degassing furnace (0.1 torr), and a molten steel having an intended composition was prepared by adding an alloy component. Thereafter, the molten steel was manufactured into a slab by continuous casting.

[Table 1]

Steel	Alloy Composition (wt%)													CutCr +Ni	Relationship 2	
	C	Si	Mn	P	S	Al	Ti	N	Cu	Cr	Ni	Nb	Sn+Sb		A value	
A	0.0018	0.020	0.193	0.0390	0.0087	0.0640	0.010	0.0014	0.075	0.039	0.029	0.018	0.019	0.143	0.69	
B	0.0019	0.020	0.193	0.0380	0.0084	0.0450	0.010	0.0015	0.103	0.054	0.041	0.018	0.021	0.198	0.69	
C	0.0020	0.019	0.191	0.0380	0.0085	0.0470	0.009	0.0013	0.140	0.072	0.053	0.019	0.020	0.265	0.68	
D	0.0015	0.019	0.197	0.0390	0.0082	0.0430	0.010	0.0013	0.180	0.088	0.067	0.019	0.022	0.335	0.68	
E	0.0015	0.019	0.193	0.038 0	0.008 8	0.036 0	0.010	0.001 5	0.220	0.104	0.078	0.018	0.020	0.402	0.69	
F	0.0013	0.018	0.193	0.038 0	0.008 3	0.048 0	0.009	0.001 4	0.380	0.172	0.130	0.018	0.021	0.682	0.71	
G	0.0016	0.028	0.160	0.019 0	0.008 0	0.039 0	0.001	0.000 7	0.075	0.039	0.029	0.005	0.001 2	0.143	2.67	
H	0.0013	0.028	0.150	0.019 0	0.008 0	0.039 0	0.001	0.000 9	0.103	0.054	0.041	0.004	0.001 3	0.198	3.00	
I	0.0015	0.027	0.150	0.020 0	0.008 0	0.037 0	0.001	0.001 0	0.140	0.072	0.053	0.005	0.001 1	0.265	2.50	
J	0.0015	0.029	0.160	0.019 0	0.008 0	0.039 0	0.001	0.000 9	0.180	0.088	0.067	0.005	0.001 2	0.335	2.67	
K	0.0014	0.030	0.150	0.019 0	0.008 0	0.034 0	0.001	0.001 0	0.220	0.104	0.078	0.005	0.001 1	0.402	2.50	
L	0.0014	0.030	0.150	0.019 0	0.008 0	0.038 0	0.001	0.001 0	0.380	0.172	0.130	0.005	0.001 3	0.682	2.50	
M	0.0022	0.001	0.069	0.014 0	0.004 7	0.021 4	0.027	0.002 7	0.113	0.071	0.070	0.009	0.003	0.143	0.19	
N	0.0016	0.004	0.058	0.009 4	0.004 3	0.040 0	0.027	0.001 7	0.136	0.105	0.081	0.007	0.004	0.198	0.17	
O	0.0028	0.005	0.064	0.0150	0.0044	0.0300	0.026	0.0028	0.131	0.068	0.068	0.009	0.009	0.265	0.18	

[Table 2]

	Specimen	Steel	Reheating	Hot-Rolling	Coiling	Cold-Rolling	Annealing	
			Temp. (°C)	Finish Temp. (°C)	Temp. (°C)	Reduction Ratio (%)	Temp. (°C)	Time (sec)
5	1	A	1210	940	700	75	810	35
	2	B	1210	940	700	75	810	35
	3	C	1210	940	700	75	810	35
10	4	D	1210	940	700	75	810	35
	5	E	1210	940	700	75	810	35
	6	F	1210	940	700	75	810	35
15	7	A	1190	920	650	75	830	33
	8	B	1190	920	650	75	830	33
	9	C	1190	920	650	75	830	33
20	10	D	1190	920	650	75	830	33
	11	E	1190	920	650	75	830	33
	12	F	1190	920	650	75	830	33
25	13	A	1170	900	600	75	850	30
	14	B	1170	900	600	75	850	30
	15	C	1170	900	600	75	850	30
30	16	D	1170	900	600	75	850	30
	17	E	1170	900	600	75	850	30
	18	F	1170	900	600	75	850	30
35	19	G	1190	920	650	75	800	35
	20	H	1190	920	650	75	800	35
	21	I	1190	920	650	75	800	35
40	22	J	1190	920	650	75	800	35
	23	K	1190	920	650	75	800	35
	24	L	1190	920	650	75	800	35
45	25	M	1190	920	650	75	850	30
	26	N	1190	920	650	75	850	30
	27	O	1190	920	650	75	850	30

[0091] Table 3 below shows measurement and evaluation of a microstructure and properties of a manufactured cold-rolled steel sheet.

[0092] The microstructure of the steel sheet was observed using an electron scanning microscope (SEM) after collecting and polishing a specimen at 1/4 of a point in a thickness direction from a surface of the steel sheet, and then performing nital etching on a cross-section of the polished specimen. After the nital etching, a structure having no irregularities on a surface of the specimen was determined as ferrite, and a structure having a spherical or lamellar structure was determined as cementite. Furthermore, an average grain size of ferrite was measured through an optical microscope with respect to the specimen. Meanwhile, both Inventive Examples and Comparative Examples included 95% or more of ferrite.

[0093] For texture evaluation of the steel sheet, a cross-section of the cold-rolled steel sheet was prepared as a specimen with an Electron Back Scattered Diffraction (EBSD) measuring device, observed in a C direction, and scanned. The measured data were rotated in a plane view direction and observed in a [001] direction, and a volume fraction of grain in a <111> direction, parallel to the [001] direction that positively affects formability was measured. {111} surfaces may be advantageous for deformation, and when the volume fraction is high, formability may be improved. For example, the higher the volume fraction of <111>||[001] is, the better the formability.

[0094] In addition, a tensile test was conducted to evaluate properties of each steel sheet. The tensile test was evaluated as a specimen collected according to the JIS5 standard based on a 0° direction with respect to a rolling direction of the rolled sheet, and a product (TS X EI) of tensile strength (TS) and elongation (EI) was calculated. In addition, for the same specimen, the Lankford value (r-value) was measured by the three-point method after 15% tensile preliminary deformation, and the average value in a rolling direction (L direction), a right angle direction (C direction), and a 45° direction (D direction) in the rolling direction were calculated by the following calculation formula. In the present disclosure, r values were shown in the order of $r_L < r_D < r_C$ size.

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

[Table 3]

Specimen	Steel	Microstructure		Properties					Relationship 1	Example
		Ferrite Grain Size (μm)	Texture Fracture (%) <111> [001]	TS (MPa)	EI (%)	TS*EI (GPa·%)	r-value	r-value* EI (%)	T value	
1	A	8.8	40.6	376	35.2	13.3	1.61	56.7	0.97	Inventive Ex. 1
2	B	8.6	44.7	390	34.6	13.5	1.62	56.0	0.96	Inventive Ex. 2
3	C	8.9	46.3	386	33.3	12.9	1.64	54.6	0.96	Inventive Ex. 3
4	D	8.5	53.5	389	32.6	12.7	1.69	55.0	0.97	Inventive Ex. 4
5	E	8.7	53.5	393	32.2	12.6	1.72	55.3	0.98	Inventive Ex. 5
6	F	8.9	55.6	402	32.1	12.9	1.82	58.3	0.97	Inventive Ex. 6
7	A	10.9	48.3	364	38.1	13.9	1.72	65.5	1.04	Inventive Ex. 7
8	B	10.3	51.2	374	37.0	13.8	1.75	64.7	1.04	Inventive Ex. 8
9	C	9.9	54.2	375	38.0	14.3	1.75	66.6	1.03	Inventive Ex. 9
10	D	10.8	56.3	378	37.1	14.0	1.80	75.2	1.04	Inventive Ex. 10
11	E	9.8	57.9	381	36.8	14.0	1.84	67.6	1.04	Inventive Ex. 11
12	F	10.9	58.0	390	36.1	14.1	1.94	70.1	1.04	Inventive Ex. 12
13	A	11.7	50.7	358	42.8	15.3	1.83	78.4	1.10	Inventive Ex. 13
14	B	12.2	51.8	363	40.5	14.7	1.86	75.3	1.11	Inventive Ex. 14
15	C	11.9	56.9	367	42.0	15.4	1.87	78.6	1.10	Inventive Ex. 15

(continued)

Specimen	Steel	Microstructure		Properties					Relationship 1	Example
		Ferrite Grain Size (μm)	Texture Fracture (%) $\langle 111 \rangle \parallel [001]$	TS (MPa)	EI (%)	TS*EI (GPa·%)	r-value	r-value*EI (%)	T value	
16	D	12.5	60.7	370	41.9	15.5	1.91	79.9	1.10	Inventive Ex. 16
17	E	11.8	61.3	373	40.7	15.2	1.96	79.9	1.11	Inventive Ex. 17
18	F	11.5	61.5	381	39.3	15.0	2.05	80.5	1.09	Inventive Ex. 18
19	G	13.2	50.6	305	47.8	14.6	1.67	79.8	1.01	Comparative Ex. 1
20	H	14.6	44.0	310	45.8	14.2	1.58	70.5	0.94	Comparative Ex. 2
21	I	13.8	38.3	314	44.9	14.1	1.40	62.8	0.82	Comparative Ex. 3
22	J	13.3	38.2	318	46.2	14.7	1.38	63.7	0.80	Comparative Ex. 4
23	K	14.2	37.6	323	45.0	14.5	1.32	59.3	0.75	Comparative Ex. 5
24	L	14.4	36.4	325	45.2	14.7	1.26	57.0	0.67	Comparative Ex. 6
25	M	16.2	55.6	316	45.6	14.4	1.80	82.1	1.06	Comparative Ex. 7
26	N	16.1	52.3	320	45.0	14.4	1.72	77.4	0.99	Comparative Ex. 8
27	O	16.2	48.2	312	45.0	14.0	1.70	76.5	1.00	Comparative Ex. 9

[Relationship 1]

$$T = R / (0.4 ([Cu] + [Cr] + [Ni]) + 1.6)$$

(In the Relationship, R is an r-value, and [Cu], [Cr], and [Ni] are a weight percent of an element corresponding thereto, respectively.)

[0095] As shown in Table 3, in Inventive Examples satisfying the alloy composition and manufacturing conditions of the present disclosure, microstructure characteristics proposed in the present disclosure were satisfied, and desired properties of the present disclosure were also secured.

[0096] Furthermore, FIG. 1 is a graph showing the r-value according to the sum of Cu, Cr, and Ni contents. As shown in FIG. 1, in Inventive Examples according to an embodiment of the present disclosure, it can be seen that the volume fraction of $\langle 111 \rangle \parallel [001]$ increases as the sum of the contents of Cu, Cr, and Ni increases, and thus the r-value increases as the contents of the elements increase.

[0097] On the other hand, Comparative Examples 1 to 9 are examples that do not satisfy the alloy composition condition proposed in the present disclosure. Accordingly, desired properties of the present disclosure may not be secured. In addition, it may be confirmed that the volume fraction of $\langle 111 \rangle \parallel [001]$ decreases as the sum of the contents of Cu, Cr, and Ni increases, and thus the r-value decreases as the contents of the elements increase.

[0098] Although the present disclosure has been described in detail through embodiments, other forms of embodiments may be also possible. Therefore, the technical idea and scope of the claims described below may not be limited to embodiments.

Claims

1. A cold-rolled steel sheet comprising:

by weight, C: 0.0500% or less, Si: 0.005% to 0.080%, Mn: 0.500% or less, Al: 0.0800% or less, P: 0.0800% or less, S: 0.0500% or less, N: 0.0300% or less, Ti: 0.001% to 0.050%, Nb: 0.001% to 0.050%, Cu: 1.000% or less, Ni: 1.000% or less, Cr: 1.000% or less, at least one of Sb or Sn: 0.500% or less, a remainder of Fe, and unavoidable impurities,
wherein a T value defined in Relationship 1 below is 0.90 to 1.20, and
wherein a tensile strength is 330 MPa or more:

[Relationship 1]

$$T = R / (0.4 ([Cu] + [Cr] + [Ni]) + 1.6)$$

where R is an r-value, and [Cu], [Cr], and [Ni] are a weight percent of an element corresponding thereto, respectively.

2. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet further comprises, by weight, Mo: 1% or less and B: 0.02% or less.

3. The cold-rolled steel sheet of claim 1, wherein Cu+Cr+Ni of the cold-rolled steel sheet is 0.7% or less, by weight.

4. The cold-rolled steel sheet of claim 1, wherein an A value defined in Relationship 2 below in the cold-rolled steel sheet is 0.40 to 1.40:

[Relationship 2]

$$A = [Mn] / 10 ([Ti] + [Nb])$$

where [Mn], [Ti], and [Nb] are a weight percent of an element corresponding thereto, respectively.

5. The cold-rolled steel sheet of claim 1, wherein a microstructure of the cold-rolled steel sheet comprises, by area, 95% or more ferrite and a remaining structure.

6. The cold-rolled steel sheet of claim 1, wherein an average grain size of ferrite in the cold-rolled steel sheet is 13.0 μm or less.

7. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a tensile strength of 330 to 420 MPa and an elongation of 32% or more.

8. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has an r-value of 1.60 or more.

9. A method of manufacturing a cold-rolled steel sheet, comprising:

reheating a steel slab including, by weight, C: 0.0500% or less, Si: 0.005% to 0.080%, Mn: 0.500% or less, Al: 0.0800% or less, P: 0.0800% or less, S: 0.0500% or less, N: 0.0300% or less, Ti: 0.001% to 0.050%, Nb: 0.001% to 0.050%, Cu: 1.000% or less, Ni: 1.000% or less, Cr: 1.000% or less, at least one of Sb or Sn: 0.500% or less, a remainder of Fe, and unavoidable impurities,
hot-rolling the reheated steel slab;
coiling the hot-rolled steel sheet;
cold-rolling the coiled steel sheet; and

annealing the cold-rolled steel sheet.

10. The method of claim 9, wherein the steel slab further comprises, by weight, Mo: 1% or less and B: 0.02% or less.

11. The method of claim 9, wherein Cu+Cr+Ni of the steel slab is 0.7% or less, by weight.

12. The method of claim 9, wherein an A value defined in Relationship 2 below in the steel slab is 0.40 to 1.40:

[Relationship 2]

$$A = [\text{Mn}] / 10 ([\text{Ti}] + [\text{Nb}])$$

where [Mn], [Ti], and [Nb] are a weight percent of an element corresponding thereto, respectively.

13. The method of claim 9, wherein the reheating is performed in a temperature range of 900 to 1300°C,

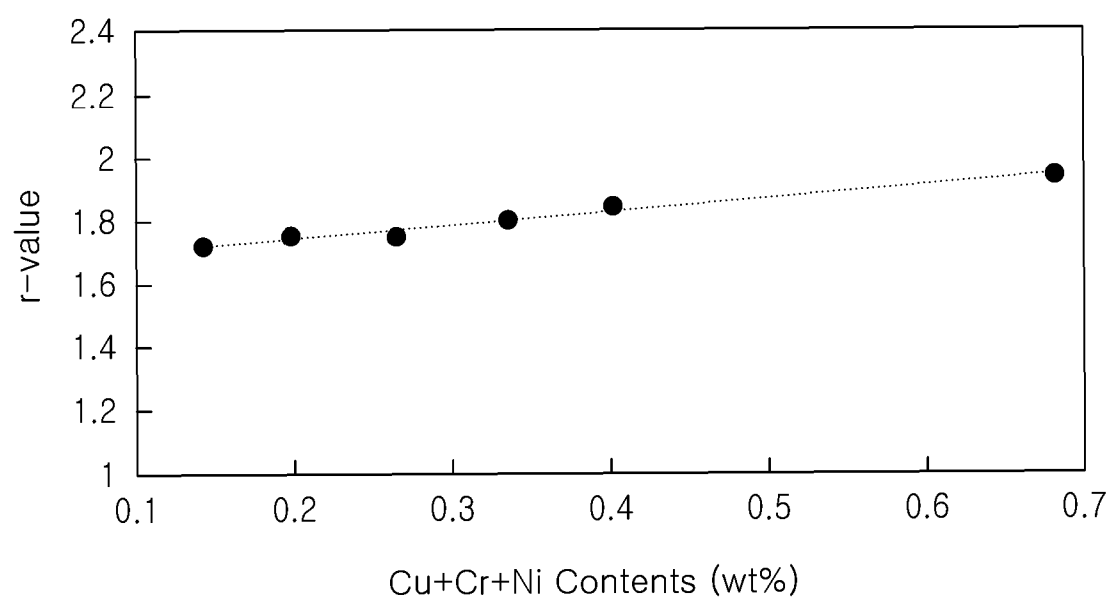
wherein the hot-rolling is performed at a finishing temperature of 880°C or higher,

wherein the coiling is performed in a temperature range of 500 to 800°C,

wherein the cold-rolling is performed at a cold-roll pressing rate of 50 to 90%, and

wherein the annealing is performed in a temperature range of 600°C or higher for 10 seconds or more.

[FIG. 1]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020338

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/50(2006.01)i; **C22C 38/48**(2006.01)i; **C22C 38/42**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/06**(2006.01)i;
C22C 38/44(2006.01)i; **C22C 38/54**(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 38/50(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(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: 페라이트(ferrite), 인장강도(tensile strength), 소둔(annealing), 냉연강판(cold rolled steel sheet), 랭크포드 값(R value), 연신율(elongation)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2011-0046653 A (HYUNDAI STEEL COMPANY) 06 May 2011 (2011-05-06) See paragraphs [0072]-[0075], claims 1-4 and table 2.	1-13
X	KR 10-2010-0025923 A (HYUNDAI STEEL COMPANY) 10 March 2010 (2010-03-10) See paragraphs [0054], [0072] and [0090]-[0094], claims 1-4 and table 2.	1-13
A	KR 10-2018-0061449 A (HYUNDAI STEEL COMPANY) 08 June 2018 (2018-06-08) See claims 1-6.	1-13
A	KR 10-0760593 B1 (JFE STEEL CORPORATION) 20 September 2007 (2007-09-20) See claims 1-6 and table 2-1.	1-13
A	KR 10-2012-0137932 A (POSCO) 24 December 2012 (2012-12-24) See claims 1-6 and table 2.	1-13

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

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“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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Date of the actual completion of the international search 13 March 2025	Date of mailing of the international search report 14 March 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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