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

(57) The objective of the present invention is to provide a cold-rolled steel sheet and a method for manufacturing same, the cold-rolled steel sheet having,

when a steel sheet for a vehicle is manufactured by recycling iron scrap, high strength and high formability even if containing residual elements.

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## Description

## Technical Field

- 5 **[0001]** The present disclosure relates to a steel sheet appropriate for an automotive material, and more particularly, to a cold-rolled steel sheet having high strength and high formability and a method for manufacturing the same.

## Background Art

- 10 **[0002]** In order to respond to the global climate crisis, automobile manufacturers are demanding the supply of automotive steel sheet having reduced CO<sub>2</sub> emissions from steel companies in stages, aiming to achieve carbon neutrality by 2050. For this reason, recently, steel companies have been developed an automotive steel sheet having reduced CO<sub>2</sub> emissions through scrap iron recycling, using a conventional blast furnace-converter steelmaking method or an electric furnace steelmaking method.

- 15 **[0003]** When the scrap iron is used as a raw material, it is difficult to remove tramp elements such as Cr, Cu, Ni, and Sn contained in the scrap iron during refining, and the elements are included in steel after the refining. Since the tramp elements have a problem of degrading the physical properties of steel or deteriorating surface quality, high-quality thin sheet products which have been represented by automotive steel sheets so far were manufactured by a method of extreme control of the contents of tramp elements while using molten iron as a raw material and significantly reducing C and N in steel in a common blast furnace-converter process.

**[0004]** Meanwhile, a technology of manufacturing an automotive steel sheet having excellent formability (workability) from an electric furnace steel containing tramp elements, using an electric furnace steelmaking method was suggested as follows.

- 25 **[0005]** Patent Documents 1 and 2 disclose cold-rolled steel sheets having excellent cold workability even with large amounts of tramp elements contained in steel, as a technology of manufacturing a cold-rolled steel sheet having excellent workability. In the present technology, a relationship between tensile strength and elongation rate of a steel sheet (TS×EI) and a relationship between a Lankford value (r-value) and an elongation rate (r-value×EI) are mentioned. However, the present technologies limit incorporation of Cu and Ni as tramp elements, in response to the problem of the Lankford value (r-value) reduced depending on the contents of tramp elements in the steel composition.

**[0006]** That is, in general, a steel sheet used as an automotive exterior panel has a Lankford value (r-value) which decreases as the tramp elements increase and formability thereof deteriorates, and the decreasing Lankford value (r-value) means that formability becomes inferior.

- 35 **[0007]** As such, a technology of manufacturing an automotive steel sheet containing tramp elements such as impurities was suggested, but an automotive steel sheet having excellent formability while having strength and ductility at or above a certain level even in the presence of the tramp elements has not been developed yet. In particular, a cold-rolled steel sheet which is appropriate for an automotive exterior panel having high strength while maintaining ductility and a Lankford value (r-value) at a level of high formability in spite of containing the tramp elements has not been provided.

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

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

## Summary of Invention

## Technical Problem

- 50 **[0008]** An aspect of the present disclosure is to provide a cold-rolled steel sheet which has high strength and high formability even with the tramp elements contained, in manufacturing an automotive steel sheet by recycling scrap iron, and a method for manufacturing the same.

**[0009]** An object of the present disclosure is not limited to the above description. Any person with ordinary skill in the art to which the present disclosure pertains will have no difficulty in understanding further objects of the present disclosure from the general details the specification of the present disclosure.

- 55 **Solution to Problem**

**[0010]** According to an aspect of the present disclosure, a cold-rolled steel sheet includes, by weight: more than 0% and 0.0500% or less of carbon (C), more than 0% and 0.080% or less of silicon (Si), more than 0% and 0.500% or less

of manganese (Mn), more than 0% and 0.080% or less of aluminum (Al), 0 to 0.080% of phosphorus (P), 0 to 0.0500% of sulfur (S), 0 to 0.0300% of nitrogen (N), 0.001 to 0.050% of titanium (Ti), 0.001 to 0.050% of niobium (Nb), 0 to 0.700% of copper (Cu), 0 to 0.700% of nickel (Ni), 0 to 0.700% of chromium (Cr), 0 to 0.700% of molybdenum (Mo), 0 to 0.0200% of boron (B), 0 to 0.5000% of antimony (Sb), 0 to 0.5000% of tin (Sn), a remainder of Fe, and other unavoidable impurities.

**[0011]** The cold-rolled steel sheet according to an example embodiment in the present disclosure may satisfy an A value defined by the following Relationship 1 of 0.40 to 1.40:

[Relationship 1]

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

wherein [Mn], [Ti], [Nb], and [N] are weight contents of each element.

**[0012]** In an example embodiment in the present disclosure, the cold-rolled steel sheet may have a total content of Cu, Ni, Cr, and Sn (Cu+Ni+Cr+Sn) of 0.7000 wt% or less.

**[0013]** The cold-rolled steel sheet of the present disclosure as such may secure excellent formability together with high strength even with certain amounts of tramp elements contained.

**[0014]** As an example, the cold-rolled steel sheet according to an example embodiment in the present disclosure may have a Lankford value (r-value) of 1.6 or more and a T value defined by the following Relationship 2 of 0.90 to 1.20:

[Relationship 2]

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

wherein R is a Lankford value (r-value), and [Cu], [Cr], [Ni], and [Sn] are weight contents of each element.

**[0015]** The cold-rolled steel sheet according to an example embodiment in the present disclosure may include ferrite in an area fraction of 95% or more and a remaining structure, as a microstructure.

**[0016]** According to another aspect of the present disclosure, a method for manufacturing a cold-rolled steel sheet includes: preparing a steel slab; reheating the steel slab in a temperature range of 900 to 1300°C; finish rolling the reheated steel slab in an austenite region at or above an Ar3 transformation point or a ferrite region at or below an Ar3 transformation point to obtain a hot-rolled steel sheet; winding the hot-rolled steel sheet at a temperature of 500°C or higher; after the winding, cold rolling the hot-rolled steel sheet at a reduction rate of 40% or more to obtain a cold-rolled steel sheet; and performing an annealing heat treatment of the cold-rolled steel sheet at 600°C or higher for 10 seconds or more.

**[0017]** In an example embodiment in the present disclosure, the steel slab may have the alloy composition described above and may satisfy Relationship 1.

**[0018]** The cold-rolled steel sheet manufactured through a series of processes as such may have high strength and excellent formability, and as an example, may satisfy Relationship 2 described above.

#### Advantageous Effects of Invention

**[0019]** According to the present disclosure, a cold-rolled steel sheet having improved formability together with high strength even with certain contents of tramp elements contained may be provided, and the cold-rolled steel sheet may be appropriately applied as an automotive material.

**[0020]** In addition, since the steel sheet of the present disclosure is manufacturing by recycling scrap iron, when the same is applied as a material of an automobile body and the like, a CO<sub>2</sub> reduction effect is excellent.

**[0021]** Various and beneficial merits and effects of the present disclosure are not limited to the descriptions above and may be more easily understood in a process of describing specific exemplary embodiments in the present disclosure.

## Best Mode for Invention

**[0022]** Technical terms used herein are only for mentioning specific example embodiments rather than limiting the present disclosure. In addition, a singular form used herein includes a plural form also, unless the phrases have a clearly opposite meaning thereto.

**[0023]** The meaning of "comprising" used in the specification embodies specific characteristics, domains, integers, steps, actions, elements, and/or components, and does not exclude the presence or addition of other specific characteristics, domains, integers, steps, actions, elements, and/or components.

**[0024]** Unless otherwise defined, all terms including technical terms and scientific terms used herein have the same meaning as commonly understood by a person with ordinary skill in the art to which the present disclosure pertains. The commonly used terms defined in the dictionary is construed as having the meaning consistent with the related technical literature and the current disclosure and are not construed as having ideal or very formal meaning unless otherwise defined.

**[0025]** Hereinafter, a cold-rolled steel sheet according to an aspect of the present disclosure, in particular, a cold-rolled steel sheet having high strength and excellent formability will be described in detail. When the content of each element is represented in the present disclosure, it should be noted that the unit is % by weight unless otherwise particularly defined. In addition, a ratio of a crystal or structure is by area unless otherwise particularly expressed.

**[0026]** The cold-rolled steel sheet according to an aspect of the present disclosure may include, by weight: more than 0% and 0.0500% or less of carbon (C), more than 0% and 0.080% or less of silicon (Si), more than 0% and 0.500% or less of manganese (Mn), more than 0% and 0.080% or less of aluminum (Al), 0 to 0.080% of phosphorus (P), 0 to 0.0500% of sulfur (S), 0 to 0.0300% of nitrogen (N), 0.001 to 0.050% of titanium (Ti), 0.001 to 0.050% of niobium (Nb), 0 to 0.700% of copper (Cu), 0 to 0.700% of nickel (Ni), 0 to 0.700% of chromium (Cr), 0 to 0.700% of molybdenum (Mo), 0 to 0.0200% of boron (B), 0 to 0.5000% of antimony (Sb), and 0 to 0.5000% of tin (Sn).

**[0027]** Hereinafter, the reason that the alloy composition of the cold-rolled steel sheet provided in the present disclosure is limited as described above will be described in detail.

Carbon (C): more than 0% and 0.0500% or less

**[0028]** Carbon (C) is an element effective for securing steel strength.

**[0029]** In an example embodiment in the present disclosure, when the content of C is more than 0.0500%, it is difficult to secure target levels of an elongation rate and a r-value value. Therefore, C may be contained at 0.0500% or less. In another example embodiment in the present disclosure, C may be 0.0400% or less.

**[0030]** Meanwhile, C is an essential element in steel manufacture, and its content is more than 0%. However, in an example embodiment in the present disclosure, when the content is less than 0.0003%, an effect obtained by reducing C may not be obtained, and an increase in steel making costs is rather caused, which is thus not preferred. Therefore, C may be included at 0.0003% or more. In another example embodiment in the present disclosure, C may be included at 0.0010% or more or 0.0015% or more.

Silicon (Si): more than 0% and 0.080% or less

**[0031]** Silicon (Si) is an element having a strength improvement effect by solid solution strengthening and is useful for strengthening ferrite and homogenizing structure to improve workability. In addition, Si is an element required for deoxidation during steel making.

**[0032]** In an example embodiment in the present disclosure, when the content of Si is more than 0.080%, plating defects such as unplating is caused during plating, and weldability of a steel sheet may be deteriorated. Thus, Si may be contained at 0.080% or less. In another example embodiment in the present disclosure, Si may be 0.070% or less.

**[0033]** Meanwhile, in an example embodiment in the present disclosure, Si may be included in an amount greater than 0%, and the content may be 0.001% or more considering the manufacturing costs.

Manganese (Mn): more than 0% and 0.500% or less

**[0034]** Manganese (Mn) is an element useful for improving strength and ductility of steel simultaneously.

**[0035]** In an example embodiment in the present disclosure, when the content of Mn is more than 0.500%, workability is reduced, which is thus not preferred. In another example embodiment in the present disclosure, Mn may be 0.400% or less.

**[0036]** Meanwhile, in an example embodiment in the present disclosure, Mn may be included in an amount greater than 0%, and the content may be 0.001% or more considering the manufacturing costs.

Aluminum (Al): more than 0% and 0.080% or less

**[0037]** Aluminum (Al) is an element which is bonded to oxygen (O) in steel to perform an deoxidation action. In addition, it is an element which strengthens ferrite, homogenizes the structure, and improves workability, similarly to Si.

**[0038]** In an example embodiment in the present disclosure, when the content of Al is more than 0.080%, workability is rather deteriorated. Therefore, Al may be included at 0.080% or less. In an example embodiment in the present disclosure, Al may be contained at 0.060% or less.

**[0039]** Meanwhile, in an example embodiment in the present disclosure, Al may be included in an amount greater than 0%. However, in order to control the content of Al to less than 0.001%, the manufacturing costs are increased, and thus, the content may be limited to 0.001% or more considering this.

Phosphorus (P): 0.080% or less

**[0040]** Phosphorus (P) is an element added for improving strength of steel, and in an example embodiment in the present disclosure, when the content of P is more than 0.080%, workability of steel is deteriorated, and brittleness is caused. Thus, P may be included at 0.080% or less. In another example embodiment in the present disclosure, P may be included at 0.070% or less.

**[0041]** Meanwhile, in an example embodiment in the present disclosure, P may be included in an amount greater than 0%, and the content may be limited to 0.001% or more considering the manufacturing costs.

Sulfur (S): 0.0500% or less

**[0042]** Sulfur (S) is an element which is inevitably added in the manufacturing process of steel and is bonded to Mn in steel to form a MnS inclusion, thereby deteriorating ductility of steel. Thus, in an example embodiment of the present disclosure, the content of S may be limited to 0.0500% or less. In an example embodiment in the present disclosure, S may be included at 0.0400% or less.

**[0043]** Meanwhile, since S is may be inevitably contained in steel, the content may be more than 0%. However, in an example embodiment in the present disclosure, in order to control the content of S to less than 0.0010%, the manufacturing costs are greatly increased. Thus, S may be limited to 0.0010% or more.

Nitrogen (N): 0.0300% or less

**[0044]** Nitrogen (N) is an element which is inevitably added in the manufacturing process of steel and causes cracks of a slab by forming a nitride in a continuous casting process. Thus, in an example embodiment of the present disclosure, the content of N may be limited to 0.0300% or less. In an example embodiment in the present disclosure, N may be included at 0.0200% or less.

**[0045]** As described above, since N is may be inevitably contained in steel, the content may be more than 0%. However, the manufacturing costs are greatly increased in order to control the content of N to less than 0.0010%, the content of N may be limited to 0.0010% or more.

Titanium (Ti): 0.001 to 0.050% and niobium (Nb): 0.001 to 0.050%

**[0046]** Titanium (Ti) and niobium (Nb) are elements which form precipitates in steel, and strength and impact toughness of steel may be improved by formation of the precipitate. In particular, Ti and Nb may prevent workability deterioration by solid solubilized C and solid solubilized N by precipitating the solid solubilized C and solid solubilized N in steel as carbides, nitrides, and the like.

**[0047]** In an example embodiment in the present disclosure, the elements may be included at 0.001% or more, respectively, and the effects described above may be obtained therefrom. However, when each content is more than 0.050%, an addition effect is saturated, the manufacturing costs are increased, and thus, the upper limit of each element may be limited to 0.050%. In an example embodiment in the present disclosure, the element may be included at 0.040% or less, respectively.

Copper (Cu): 0 to 0.700% and nickel (Ni): 0 to 0.700%

**[0048]** Copper (Cu) and nickel (Ni) are elements which stabilize austenite and suppress corrosion. In addition, Cu and Ni are elements which are concentrated on the surface of a steel sheet, prevent the intrusion of hydrogen moving into steel, and are useful for suppressing hydrogen delayed breakdown.

**[0049]** In an example embodiment in the present disclosure, when the contents of Cu and Ni are excessive, respectively, workability may become inferior, and thus, the contents may be limited to 0.700% or less, respectively. In another example embodiment in the present disclosure, Cu and Ni may be included at 0.600% or less, respectively.

**[0050]** Meanwhile, in an example embodiment in the present disclosure, Cu and Ni may be included in an amount greater than 0%, and in order to sufficiently obtain the effect from these elements, they may be contained at 0.001% or more, respectively.

Chromium (Cr): 0 to 0.700% and molybdenum (Mo): 0 to 0.700%

**[0051]** Chromium (Cr) and molybdenum (Mo) are elements which suppresses decomposition of austenite during an alloying treatment of a steel sheet and stabilize austenite similarly to Mn.

**[0052]** In an example embodiment in the present disclosure, when the contents of Cr and Mo are excessive, workability may be deteriorated, and thus, the contents may be limited to 0.700% or less, respectively. In another example embodiment in the present disclosure, Cr and Mo may be included at 0.600% or less.

**[0053]** Meanwhile, in an example embodiment in the present disclosure, Cr and Mo may be included in an amount greater than 0%, and in order to sufficiently obtain the effect from these elements, they may be contained at 0.001% or more, respectively.

Boron (B): 0 to 0.0200%

**[0054]** Boron (B) is an element which improves quenchability of steel to increase strength and suppresses nucleation of a crystal grain boundary.

**[0055]** In an example embodiment in the present disclosure, when the content of B is more than 0.0200%, the deep drawing property of steel may be deteriorated. Therefore, B may be included at 0.0200% or less. According to another example embodiment, B may be included at 0.0100% or less. Meanwhile, in an example embodiment in the present disclosure, in order to obtain the effect of adding B, B may be included at 0.0001% or more.

Antimony (Sb): 0 to 0.5000% and tin (Sn): 0 to 0.5000%

**[0056]** Antimony (Sb) and tin (Sn) are elements which improve plating wettability and plating adhesion of steel. In an example embodiment in the present disclosure, when the contents of the elements are more than 0.5000%, respectively, the brittleness of steel is increased to cause cracks during hot working or cold working, and thus, the content of each element may be limited to 0.5000% or less. In an example embodiment in the present disclosure, Sb and Sn may be included at 0.4000% or less, respectively. Meanwhile, in terms of sufficiently obtaining the effect of adding these elements, they may be included at 0.0005% or more, respectively.

**[0057]** In an example embodiment in the present disclosure, the steel sheet may include Fe and other inevitable impurities in addition to the components described above. However, since in a common manufacturing process, unintended impurities may be unavoidably incorporated from raw materials or the surrounding environment, these may not be completely excluded. Since these impurities are known to any person with ordinary knowledge in the art, the entire contents thereof are not particularly mentioned in the present specification. In addition, further addition of effective components other than the components described above is not completely excluded.

**[0058]** The total content of Cu, Ni, Cr, and Sn (Cu+Ni+Cr+Sn) in the cold-rolled steel sheet according to an example embodiment in the present disclosure may be 0.7000 wt% or less.

**[0059]** Since the cold-rolled steel sheet according to an example embodiment in the present disclosure uses scrap iron containing various impurity elements as a material, it may include elements such as Cu, Ni, Cr, and Sn as alloy components forming the cold-rolled steel sheet. As described above, when the contents of them are excessive, the physical properties and the like to be intended in the present disclosure may not be obtained. Thus, in an example embodiment in the present disclosure, the total content of Cu, Ni, Cr, and Sn in the composition of the cold-rolled steel sheet may be limited to 0.7000% or less.

**[0060]** Meanwhile, though the lower limit of the total content of the elements described above is not particularly limited, the elements may be contained at 0.001% or more.

**[0061]** The cold-rolled steel sheet according to an example embodiment in the present disclosure may satisfy an A value of 0.40 to 1.40, the A value showing a content relationship of specific elements being defined by the following Relationship 1:

[Relationship 1]

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

wherein [Mn], [Ti], [Nb], and [N] are weight contents of each element.

**[0062]** When the cold-rolled steel sheet is manufactured using scrap iron, tramp elements contained in the scrap iron may be incorporated into the manufactured cold-rolled steel sheet, and in general, the higher the contents of the tramp elements is, the inferior the formability of the cold-rolled steel sheet is.

**[0063]** Considering this, the inventors of the present disclosure conducted an in-depth study in order to manufacture a cold-rolled steel sheet having excellent formability even with certain tramp elements contained, thereby deriving Relationship 1. That is, in an example embodiment in the present disclosure, formability to be targeted as well as strength may be secured by controlling a relationship of the content of Mn together with the contents of Ti, Nb, and N forming the precipitate as Relationship 1. When the A value according to Relationship 1 is less than 0.40, the target strength is not be secured by the excessively decreased content of Mn favorable for securing strength. However, when the value is more than 1.40, the precipitate in steel is not properly formed, and thus, formability is deteriorated by excessive remaining of solid solubilized C, solid solubilized N, and the like in steel.

**[0064]** The cold-rolled steel sheet according to an example embodiment in the present disclosure may include a ferrite phase as a main structure in the microstructure, and as an example, may include the ferrite phase in an area fraction of 95% or more. Herein, it is fine if the ferrite phase is a ferrite single phase.

**[0065]** However, in terms of improving strength, the cold-rolled steel sheet according to an example embodiment in the present disclosure may include 5% or less of a remaining structure in addition to ferrite. Though the remaining structure is not particularly limited, as an example, the remaining structure may be a hard phase such as a martensite and bainite phases or a pearlite phase. These remaining structures may be collectively referred to as a low-temperature transformation phase.

**[0066]** The cold-rolled steel sheet according to an example embodiment in the present disclosure may have excellent formability characteristics.

**[0067]** Specifically, according to an example embodiment in the present disclosure, the cold-rolled steel sheet may have a Lankford value (r-value) of 1.6 or more. As such, the cold-rolled steel sheet according to an example embodiment in the present disclosure may have excellent formability of the r value of 1.6 or more.

**[0068]** The cold-rolled steel sheet according to an example embodiment in the present disclosure may have targeted formability even when the contents of tramp elements contained in steel, in particular, Cu, Ni, Cr, and Sn are relatively high, and this is intended to be defined by the following Relationship 2:

[Relationship 2]

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

wherein R is a Lankford value (r-value), and [Cu], [Cr], [Ni], and [Sn] are weight contents of each element.

**[0069]** That is, the cold-rolled steel sheet according to an example embodiment in the present disclosure may have a T value defined by the following Relationship 2 satisfying 0.90 to 1.20, and the characteristics mean that there is a tendency in which even when the contents of the tramp elements are increased, the r-value is not lowered and rather increased. As a result, this means that according to an example embodiment in the present disclosure, the contents of the tramp elements contained in steel may be secured to a certain range, and also the formability of the cold-rolled steel sheet may be secured within the range.

**[0070]** When the value of Relationship 2 according to an example embodiment in the present disclosure is less than 0.90, as the contents of the tramp elements of the alloy composition of steel is increased, the r-value is lowered, which may cause a problem in securing formability. However, when the value is more than 1.20, there is no problem in securing formability, but the strength may be greatly lowered.

**[0071]** Meanwhile, the cold-rolled steel sheet according to an example embodiment in the present disclosure may secure high ductility while having high strength. As an example, the cold-rolled steel sheet may have a tensile strength of 390 MPa or more and an elongation rate of 32% or more.

**[0072]** Furthermore, the cold-rolled steel sheet may satisfy a product (TS×EI) of the tensile strength and the elongation rate of 13.0 to 16.0 GPa·%, and a product (r-value×EI) of the Lankford value (r-value) and the elongation rate of 55.0 to 75.0%.

**[0073]** Hereinafter, the method for manufacturing a cold-rolled steel sheet according to another aspect of the present

disclosure will be described in detail.

**[0074]** In an example embodiment in the present disclosure, the cold-rolled steel sheet may be obtained by performing a series of processes, for example, [steel slab heating - hot rolling - winding - cooling - cold rolling - annealing]. Each process step will be described in detail, and the following manufacturing process corresponds to an example for manufacturing the cold-rolled steel sheet of the present disclosure.

[Steel slab heating]

**[0075]** A steel slab may be prepared and then heated. Herein, the steel slab may be a steel ingot. In an example embodiment in the present disclosure, the steel slab may have the alloy composition described above, and thus, the description of the alloy composition of the steel slab is replaced with the above description.

**[0076]** In an example embodiment in the present disclosure, when the prepared steel slab or steel ingot is heated, the heating temperature may be in a range of 900 to 1300°C. When the heating temperature is higher than 1300°C, the temperature reached the melting point of steel so that the steel may melt, and the workability and plating adhesion of steel may be deteriorated. However, when the temperature is lower than 900°C, a rolling load may be increased during subsequent hot rolling to deteriorate hot rolling stability. In an example embodiment in the present disclosure, the heating may be performed at 1160°C or lower.

**[0077]** According to an example embodiment in the present disclosure, the steel slab or steel ingot may be manufactured through an electric furnace or a new blast furnace-converter process, and as the raw material used in the electric furnace or blast furnace-converter process, pig iron is used together with scrap iron. Herein, the pig iron refers to molten iron obtained in the blast furnace-converter process or its corrugate, hot briquette iron (HBI), or the like.

**[0078]** The electric furnace may perform a desulfurization treatment by ladle refining after steel tapping from the electric furnace, and desulfurization and a vacuum degassing treatment of a subsequent process may be performed. In addition, alloy components are added to the steel obtained in the electric furnace while performing a degassing treatment, thereby adjusting to the final desired alloy components. Herein, the vacuum degassing treatment may be generally a RH method and a DH method, but oxygen injection into a degassing tank may be performed in parallel. Oxygen injection includes an oxygen injection method using a top-blowing lance.

[Hot rolling]

**[0079]** The heated steel slab or steel ingot may be hot rolled to obtain a hot-rolled steel sheet.

**[0080]** In an example embodiment in the present disclosure, in terms of improving workability and plating adhesion of the steel sheet, a finish temperature during hot rolling may be in an austenite region at or above an Ar3 transformation point or a ferrite region at or below an Ar3 transformation point. However, when the finish temperature is too low, a rolling load is increased during hot rolling, and thus, the lower limit may be limited to 800°C or higher. In another example embodiment in the present disclosure, the finish temperature may be 880°C or higher.

[Winding]

**[0081]** The hot-rolled steel sheet obtained by the hot rolling may be wound to a coil shape.

**[0082]** In an example embodiment in the present disclosure, in terms of improving high strength and high formability of a steel sheet, a winding process may be performed at a temperature of 500°C or higher. However, when the temperature is higher than 800°C, a problem of forming an excessively thick scale on the surface of a hot rolled coil may be caused. In an example embodiment in the present disclosure, the winding temperature may be 600°C or higher.

[Cold rolling]

**[0083]** The hot rolled coil obtained by the winding process may be cold rolled to obtain a cold rolled steel sheet. Herein, before performing the cold rolling, the hot rolled coil is in a cooled (air cooled) to room temperature, and the cooled hot rolled coil as such may be cold rolled while uncoiling.

**[0084]** In an example embodiment in the present disclosure, the cold rolling may be performed at a cold rolling reduction rate of 40% or more. When the cold rolling reduction rate is less than 40%, it may be difficult to secure a target thickness, and the workability of a steel sheet may be inferior. According to an example embodiment in the present disclosure, though the upper limit of the cold rolling reduction rate during the cold rolling is not particularly limited, a cold rolling load may be caused when the reduction rate is excessive, and thus, it may be limited to 90% or less considering this.

[Annealing]

**[0085]** The manufactured cold-rolled steel sheet may be annealing heat treated.

**[0086]** In an example embodiment in the present disclosure, the annealing heat treatment process may be any common conditions applied to the manufacture of a cold-rolled steel sheet, and a box type annealing method as well as a continuous annealing method may be applied.

**[0087]** As an example, when the continuous annealing method is applied, the annealing heat treatment may be performed under the conditions of heating the cold-rolled steel sheet to 600°C or higher and then maintaining it for 10 seconds. When the temperature during the annealing heat treatment is lower than 600°C or an annealing time is less than 10 seconds, recrystallization does not sufficiently occur in the annealing process, and the workability of steel may not be secured.

**[0088]** According to an example embodiment in the present disclosure, the upper limits of temperature and time during the annealing heat treatment are not particularly limited. However, considering the concerns about equipment trouble due to annealing at a high temperature and inferiority in powdering properties, the upper limits may be set to 960°C and 15 minutes, respectively. That is, the temperature during the annealing heat treatment is too high or the heat treatment is performed for a long time, the powdering properties of the plated steel sheet obtained later by the plating process may be deteriorated.

**[0089]** According to another example embodiment in the present disclosure, the annealing heat treatment process of the cold-rolled steel sheet may be performed at 800°C or higher. According to another example embodiment, the annealing heat treatment process may be performed at 900°C or lower.

**[0090]** The cold-rolled steel sheet manufactured through the series of processes described above may have the strength and formability targeted in the present disclosure.

**[0091]** In particular, the cold-rolled steel sheet according to an example embodiment in the present disclosure may have a Lankford value (r-value) of 1.6 or more, a tensile strength of 390 MPa or more, and an elongation rate of 32% or more.

**[0092]** In addition to this, the cold-rolled steel sheet may satisfy a product (TS×EI) of tensile strength (TS) and elongation rate (EI) of 13.4 to 15.6 GPa·% and a product (r-value×EI) of Lankford value (r-value) and elongation rate of 55.4 to 70.0%.

**[0093]** Meanwhile, the cold-rolled steel sheet according to an example embodiment in the present disclosure, that is, the cold-rolled steel sheet manufactured through a series of processes may be further subjected to a surface treatment process, if necessary, and the surface treatment process herein may be performed after the annealing heat treatment.

**[0094]** According to an example embodiment in the present disclosure, the surface treatment process may be a process such as plating and enameling, and among them, the plating may be galvanizing, tin plating, and the like.

**[0095]** In addition to this, the cold-rolled steel sheet which was subjected to a surface treatment process according to an example embodiment in the present disclosure may be further specially treated, if necessary. As an example, the special treatment may be performed after galvanizing. Herein, the special treatment may be performed in order to improve chemical conversion treatment, weldability, press forming, corrosion resistance, and the like of a steel sheet.

Mode for Invention

**[0096]** Hereinafter, the present disclosure will be specifically described through the following examples. However, it should be noted that the following examples are only for describing the present disclosure by illustration and not intended to limit the scope of right of the present disclosure. The reason is that the right scope of the present disclosure is determined by the matters described in the claims and reasonably inferred therefrom.

#### (Examples)

**[0097]** A steel slab having the alloy component system of the following Table 1 was prepared. The steel slab was subjected to [reheating - hot rolling - winding - cooling] processes according to each condition shown in the following Table 2 to manufacture a hot-rolled steel sheet. Thereafter, each hot-rolled steel sheet was subjected to a series of subsequent processes (cold rolling - annealing heat treatment) shown in the following Table 2, thereby obtaining a cold-rolled steel sheet.

**[0098]** The steel slab was obtained by the following processes. First, scrap iron combined with the existing molten iron of a blast furnace was added to an electric furnace to obtain a molten steel, the molten steel was transferred to a ladle and subjected to a vacuum degassing treatment with RH degassing (0.1 torr), and simultaneously alloy components were added to manufacture a molten steel having an intended composition. Thereafter, the molten steel was manufactured into a slab by continuous casting.

**[0099]** The microstructure and mechanical properties of the manufactured steel sheet were measured and evaluated, and all results are shown in the following Table 3.

**[0100]** First, the microstructure of each cold-rolled steel sheet was observed using a scanning electron microscope (SEM) after collecting a specimen at  $t/4$  in the thickness ( $t$ , mm) direction and polishing it, and Nital etching the cross section of the polished specimen. After the Nital etching, a structure having no unevenness on the surface of the specimen was determined as ferrite, and a structure having a spherical or acicular structure was determined as cementite.

**[0101]** In addition, for evaluation of the physical properties of each cold-rolled steel sheet, a tensile test was performed. The tensile test was performed with a specimen collected according to the standard of JIS 5 based on the direction of  $90^\circ$  to the rolling direction of a rolled steel material. At this time, after obtaining the results of tensile strength and ductility, the product ( $TS \times EI$ ) of the tensile strength (TS) and the elongation rate (EI) was calculated. In addition, for the same specimen, a Lankford value (r-value) was measured with a 3-point method after a 15% tensile pre-deformation, and the average the values in the rolling direction (L direction), in the perpendicular direction to the rolling direction (C direction), and in a  $45^\circ$  direction to the rolling direction (D direction) was calculated by the following

Calculation Formula:

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

[Table 1]

| Steel type | Alloy component system (wt%) |       |       |        |        |        |        |        |        |       |       |       |        |                 | Relation ship 1 |
|------------|------------------------------|-------|-------|--------|--------|--------|--------|--------|--------|-------|-------|-------|--------|-----------------|-----------------|
|            | C                            | Si    | Mn    | P      | S      | Al     | N      | Ti     | Nb     | Cu    | Cr    | Ni    | Sn     | (Cu+Cr +Ni+Sn ) |                 |
| A          | 0.0033                       | 0.032 | 0.229 | 0.0449 | 0.0051 | 0.0324 | 0.0058 | 0.0212 | 0.0209 | 0.070 | 0.069 | 0.040 | 0.0160 | 0.1950          | 0.48            |
| B          | 0.0029                       | 0.031 | 0.227 | 0.0447 | 0.0048 | 0.0320 | 0.0059 | 0.0211 | 0.0210 | 0.067 | 0.065 | 0.037 | 0.0160 | 0.1850          | 0.47            |
| C          | 0.0028                       | 0.032 | 0.227 | 0.0445 | 0.0048 | 0.0324 | 0.0056 | 0.0211 | 0.0207 | 0.066 | 0.064 | 0.037 | 0.0150 | 0.1820          | 0.48            |
| D          | 0.0028                       | 0.030 | 0.225 | 0.0446 | 0.0047 | 0.0322 | 0.0057 | 0.0210 | 0.0206 | 0.066 | 0.065 | 0.038 | 0.0160 | 0.1850          | 0.48            |
| E          | 0.0026                       | 0.031 | 0.226 | 0.0445 | 0.0046 | 0.0323 | 0.0055 | 0.0212 | 0.0207 | 0.068 | 0.066 | 0.038 | 0.0150 | 0.1870          | 0.48            |
| F          | 0.0021                       | 0.030 | 0.226 | 0.0446 | 0.0047 | 0.0323 | 0.0054 | 0.0211 | 0.0208 | 0.068 | 0.066 | 0.038 | 0.0150 | 0.1870          | 0.48            |
| XA         | 0.0016                       | 0.028 | 0.160 | 0.0190 | 0.0080 | 0.0390 | 0.0007 | 0.0010 | 0.0050 | 0.075 | 0.039 | 0.029 | 0.0012 | 0.1442          | 2.39            |
| XB         | 0.0013                       | 0.028 | 0.150 | 0.0190 | 0.0080 | 0.0390 | 0.0009 | 0.0010 | 0.0040 | 0.103 | 0.054 | 0.041 | 0.0013 | 0.1993          | 2.54            |
| XC         | 0.0015                       | 0.027 | 0.150 | 0.0200 | 0.0080 | 0.0370 | 0.0010 | 0.0010 | 0.0050 | 0.140 | 0.072 | 0.053 | 0.0011 | 0.2661          | 2.14            |
| XD         | 0.0015                       | 0.029 | 0.160 | 0.0190 | 0.0080 | 0.0390 | 0.0009 | 0.0010 | 0.0050 | 0.180 | 0.088 | 0.067 | 0.0012 | 0.3362          | 2.32            |
| XE         | 0.0014                       | 0.030 | 0.150 | 0.0190 | 0.0080 | 0.0340 | 0.0010 | 0.0010 | 0.0050 | 0.220 | 0.104 | 0.078 | 0.0011 | 0.4031          | 2.14            |
| XF         | 0.0014                       | 0.030 | 0.150 | 0.0190 | 0.0080 | 0.0380 | 0.0010 | 0.0010 | 0.0050 | 0.380 | 0.172 | 0.130 | 0.0013 | 0.6833          | 2.14            |
| XG         | 0.0020                       | 0.003 | 0.118 | 0.0108 | 0.0031 | 0.023  | 0.0031 | 0.0037 | 0.0096 | 0.066 | 0.042 | 0.030 | 0.006  | 0.1440          | 0.24            |

[Table 2]

|    |            |                            |                                 |                          |                                 |                            |                    |                       |
|----|------------|----------------------------|---------------------------------|--------------------------|---------------------------------|----------------------------|--------------------|-----------------------|
| 5  | Steel type | Reheating temperature (°C) | Finish rolling temperature (°C) | Winding temperature (°C) | Cold rolling reduction rate (%) | Annealing temperature (°C) | Annealing time (s) | Classification        |
|    | A          | 1220                       | 940                             | 700                      | 75                              | 810                        | 35                 | Inventive Example 1   |
| 10 | B          | 1220                       | 940                             | 700                      | 75                              | 810                        | 35                 | Inventive Example 2   |
|    | C          | 1220                       | 940                             | 700                      | 75                              | 810                        | 35                 | Inventive Example 3   |
| 15 | D          | 1220                       | 940                             | 700                      | 75                              | 810                        | 35                 | Inventive Example 4   |
|    | E          | 1220                       | 940                             | 700                      | 75                              | 810                        | 35                 | Inventive Example 5   |
| 20 | F          | 1220                       | 940                             | 700                      | 75                              | 810                        | 35                 | Inventive Example 6   |
|    | A          | 1200                       | 920                             | 650                      | 75                              | 830                        | 33                 | Inventive Example 7   |
| 25 | B          | 1200                       | 920                             | 650                      | 75                              | 830                        | 33                 | Inventive Example 8   |
|    | C          | 1200                       | 920                             | 650                      | 75                              | 830                        | 33                 | Inventive Example 9   |
| 30 | D          | 1200                       | 920                             | 650                      | 75                              | 830                        | 33                 | Inventive Example 10  |
|    | E          | 1200                       | 920                             | 650                      | 75                              | 830                        | 33                 | Inventive Example 11  |
| 35 | F          | 1200                       | 920                             | 650                      | 75                              | 830                        | 33                 | Inventive Example 12  |
|    | A          | 1180                       | 900                             | 600                      | 75                              | 850                        | 30                 | Inventive Example 13  |
| 40 | B          | 1180                       | 900                             | 650                      | 75                              | 850                        | 30                 | Inventive Example 14  |
|    | C          | 1180                       | 900                             | 650                      | 75                              | 850                        | 30                 | Inventive Example 15  |
| 45 | D          | 1180                       | 900                             | 650                      | 75                              | 850                        | 30                 | Inventive Example 16  |
|    | E          | 1180                       | 900                             | 650                      | 75                              | 850                        | 30                 | Inventive Example 17  |
| 50 | F          | 1180                       | 900                             | 650                      | 75                              | 850                        | 30                 | Inventive Example 18  |
|    | XA         | 1200                       | 920                             | 650                      | 75                              | 830                        | 35                 | Comparative Example 1 |
| 55 | XB         | 1200                       | 920                             | 650                      | 75                              | 830                        | 35                 | Comparative Example 2 |
|    | XC         | 1200                       | 920                             | 650                      | 75                              | 830                        | 35                 | Comparative Example 3 |
|    | XD         | 1200                       | 920                             | 650                      | 75                              | 830                        | 35                 | Comparative Example 4 |

(continued)

| Steel type | Reheating temperature (°C) | Finish rolling temperature (°C) | Winding temperature (°C) | Cold rolling reduction rate (%) | Annealing temperature (°C) | Annealing time (s) | Classification        |
|------------|----------------------------|---------------------------------|--------------------------|---------------------------------|----------------------------|--------------------|-----------------------|
| XE         | 1200                       | 920                             | 650                      | 75                              | 830                        | 35                 | Comparative Example 5 |
| XF         | 1200                       | 920                             | 650                      | 75                              | 830                        | 53                 | Comparative Example 6 |
| XG         | 1180                       | 920                             | 700                      | 75                              | 850                        | 30                 | Comparative Example 7 |

[Table 3]

| Classification        | YS (MPa) | TS (MPa)   | EI (%) | TS×EI (GPa·%) | r-value     | r-value×EI (%) | Relationship 2 (T value) |
|-----------------------|----------|------------|--------|---------------|-------------|----------------|--------------------------|
| Inventive Example 1   | 330      | 408        | 35     | 14.3          | 1.62        | 56.7           | 0.97                     |
| Inventive Example 2   | 293      | 394        | 34     | 13.4          | 1.63        | 55.4           | 0.97                     |
| Inventive Example 3   | 292      | 393        | 35     | 13.8          | 1.65        | 57.8           | 0.99                     |
| Inventive Example 4   | 291      | 392        | 36     | 14.1          | 1.68        | 60.5           | 1.00                     |
| Inventive Example 5   | 290      | 390        | 36     | 14.0          | 1.67        | 60.1           | 1.00                     |
| Inventive Example 6   | 289      | 390        | 37     | 14.4          | 1.68        | 62.2           | 1.00                     |
| Inventive Example 7   | 310      | 400        | 36     | 14.4          | 1.64        | 59.0           | 0.98                     |
| Inventive Example 8   | 301      | 393        | 37     | 14.5          | 1.65        | 61.1           | 0.99                     |
| Inventive Example 9   | 311      | 399        | 37     | 14.8          | 1.64        | 60.7           | 0.98                     |
| Inventive Example 10  | 306      | 398        | 37     | 14.7          | 1.66        | 61.4           | 0.99                     |
| Inventive Example 11  | 300      | 404        | 36     | 14.5          | 1.67        | 60.1           | 1.00                     |
| Inventive Example 12  | 298      | 402        | 38     | 15.3          | 1.67        | 63.5           | 1.00                     |
| Inventive Example 13  | 301      | 400        | 38     | 15.2          | 1.69        | 64.2           | 1.01                     |
| Inventive Example 14  | 296      | 395        | 39     | 15.4          | 1.71        | 66.7           | 1.02                     |
| Inventive Example 15  | 287      | 392        | 39     | 15.3          | 1.72        | 67.1           | 1.03                     |
| Inventive Example 16  | 290      | 394        | 38     | 15.0          | 1.73        | 65.7           | 1.03                     |
| Inventive Example 17  | 294      | 390        | 40     | 15.6          | 1.74        | 69.6           | 1.04                     |
| Inventive Example 18  | 292      | 391        | 40     | 15.6          | 1.75        | 70.0           | 1.04                     |
| Comparative Example 1 | 197      | <u>307</u> | 47.4   | 14.6          | 1.66        | <u>78.7</u>    | 1.00                     |
| Comparative Example 2 | 206      | <u>312</u> | 45.2   | 14.1          | <u>1.53</u> | 69.2           | 0.91                     |
| Comparative Example 3 | 211      | <u>315</u> | 44.3   | 14.0          | <u>1.39</u> | 61.6           | <u>0.81</u>              |
| Comparative Example 4 | 212      | <u>319</u> | 45.3   | 14.5          | <u>1.37</u> | 62.1           | <u>0.79</u>              |
| Comparative Example 5 | 214      | <u>323</u> | 44.3   | 14.3          | <u>1.30</u> | 57.6           | <u>0.74</u>              |
| Comparative Example 6 | 215      | <u>325</u> | 44.6   | 14.5          | <u>1.25</u> | 55.8           | <u>0.67</u>              |
| Comparative Example 7 | 161      | <u>304</u> | 45.0   | 13.7          | 2.01        | <u>90.5</u>    | <u>1.21</u>              |

The r-values of the inventive examples were shown in the size order of  $r_L < r_D < r_C$ .

All of the microstructures of the inventive examples were confirmed to have 95% or more of ferrite and remaining structures. Meanwhile, there was also a case of a ferrite single phase (100%).

[0102] As shown in Tables 1 to 3, Inventive Examples 1 to 18 which satisfied the alloy component system and the manufacturing conditions according to an example embodiment in the present disclosure were confirmed to have the desired physical properties, that is, high ductility and high formability while having high strength. In particular, the formability was able to be secured even when certain amounts of tramp elements were contained, by controlling contents of specific elements.

[0103] However, Comparative Examples 1 to 7 which did not satisfy the alloy component system according to an example embodiment in the present disclosure had at least one inferior physical property. In particular, Comparative Examples 1 to 7 are examples of being out of the value of Relationship 1 according to an example embodiment in the present disclosure. Among them, since Comparative Examples 1 to 6 did not exhibit the effect of adding precipitation forming elements, the target strength was not able to be secured. In addition, since Comparative Examples 3 to 6 contained relative large amounts of tramp elements, Relationship 2 was not able to be satisfied and a tendency of inferior formability was shown. Meanwhile, Comparative Example 7 had lower strength due to a lower content of Mn.

## Claims

1. A cold-rolled steel sheet comprising, by weight: more than 0% and 0.0500% or less of carbon (C), more than 0% and 0.080% or less of silicon (Si), more than 0% and 0.500% or less of manganese (Mn), more than 0% and 0.080% or less of aluminum (Al), 0 to 0.080% of phosphorus (P), 0 to 0.0500% of sulfur (S), 0 to 0.0300% of nitrogen (N), 0.001 to 0.050% of titanium (Ti), 0.001 to 0.050% of niobium (Nb), 0 to 0.700% of copper (Cu), 0 to 0.700% of nickel (Ni), 0 to 0.700% of chromium (Cr), 0 to 0.700% of molybdenum (Mo), 0 to 0.0200% of boron (B), 0 to 0.5000% of antimony (Sb), 0 to 0.5000% of tin (Sn), a remainder of Fe, and other unavoidable impurities,

wherein the cold-rolled steel sheet has an A value defined by the following Relationship 1 of 0.40 to 1.40:

[Relationship 1]

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

wherein [Mn], [Ti], [Nb], and [N] are weight contents of each element.

2. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a total content of Cu, Ni, Cr, and Sn (Cu+Ni+Cr+Sn) of 0.7000 wt% or less.

3. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a Lankford value (r-value) of 1.6 or more, and

a T value defined by the following Relationship 2 of 0.90 to 1.20:

[Relationship 2]

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

wherein R is a Lankford value (r-value), and [Cu], [Cr], [Ni], and [Sn] are weight contents of each element.

4. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet includes ferrite in an area fraction of 95% or more and a remaining structure as a microstructure.

5. The cold-rolled steel sheet of claim 1,

wherein the cold-rolled steel sheet has a tensile strength of 390 MPa or more and an elongation rate of 32% or more, and

a product (TS×EI) of the tensile strength and the elongation rate satisfies 13.0 to 16.0 GPa·%.

6. The cold-rolled steel sheet of claim 1, wherein a product (r-value×EI) of the Lankford value (r-value) and the elongation rate satisfies 55.0 to 75.0%.

7. A method for manufacturing a cold-rolled steel sheet, the method comprising:

preparing a steel slab which includes, by weight: more than 0% and 0.0500% or less of carbon (C), more than 0% and 0.080% or less of silicon (Si), more than 0% and 0.500% or less of manganese (Mn), more than 0% and 0.080% or less of aluminum (Al), 0 to 0.080% of phosphorus (P), 0 to 0.0500% of sulfur (S), 0 to 0.0300% of nitrogen (N), 0.001 to 0.050% of titanium (Ti), 0.001 to 0.050% of niobium (Nb), 0 to 0.700% of copper (Cu), 0 to 0.700% of nickel (Ni), 0 to 0.700% of chromium (Cr), 0 to 0.700% of molybdenum (Mo), 0 to 0.0200% of boron (B), 0 to 0.5000% of antimony (Sb), 0 to 0.5000% of tin (Sn), a remainder of Fe, and other unavoidable impurities, and has an A value defined by the following Relationship 1 of 0.40 to 1.40;  
 reheating the steel slab in a temperature range of 900 to 1300°C;  
 finish rolling the reheated steel slab in an austenite region at or above an Ar3 transformation point or a ferrite region at or below an Ar3 transformation point to obtain a hot-rolled steel sheet;  
 winding the hot-rolled steel sheet at a temperature of 500°C or higher;  
 after the winding, cold rolling the hot-rolled steel sheet at a reduction rate of 40% or more to obtain a cold-rolled steel sheet; and  
 performing an annealing heat treatment of the cold-rolled steel sheet at 600°C or higher for 10 seconds or more:

[Relationship 1]

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

wherein [Mn], [Ti], [Nb], and [N] are weight contents of each element.

8. The method for manufacturing a cold-rolled steel sheet of claim 7, wherein the steel slab has a total content of Cu, Ni, Cr, and Sn (Cu+Ni+Cr+Sn) of 0.7000 wt% or less.

9. The method for manufacturing a cold-rolled steel sheet of claim 7,

wherein after the annealing heat treatment, the cold-rolled steel sheet has a Lankford value (r-value) of 1.6 or more, and  
 a T value defined by the following Relationship 2 of 0.90 to 1.20:

[Relationship 2]

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

wherein R is a Lankford value (r-value), and [Cu], [Cr], [Ni], and [Sn] are weight contents of each element.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019734

**A. CLASSIFICATION OF SUBJECT MATTER**

**C22C 38/44**(2006.01)i; **C22C 38/50**(2006.01)i; **C22C 38/54**(2006.01)i; **C22C 38/42**(2006.01)i; **C22C 38/00**(2006.01)i;  
**C21D 8/02**(2006.01)i; **C21D 9/46**(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 38/44(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C21D 9/48(2006.01); C22C 38/00(2006.01);  
C22C 38/04(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: 탄소(carbon), 실리콘(silicon), 망간(manganese), 알루미늄(aluminum), 티타늄(titanium), 니오븀(niobium), 구리(copper), 크롬(chromium), 몰리브덴(molybdenum), 붕소(boron), 안티몬(antimony), 주석(tin), 랭크포드값(R-value, R value), 연신율(elongation, EL), 인장강도(tensile strength, TS), 페라이트(ferrite), 냉연강판(cold Rolled Steel, CRS), 소둔(annealing)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                          | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | KR 10-2010-0025923 A (HYUNDAI STEEL COMPANY) 10 March 2010 (2010-03-10)<br>See paragraphs [0072] and [0090]-[0094], claims 1-4 and table 2. | 1-3,6-9               |
| Y         |                                                                                                                                             | 4-5                   |
| Y         | KR 10-0760593 B1 (JFE STEEL CORPORATION) 20 September 2007 (2007-09-20)<br>See paragraphs [0115], [0117] and [0184], claim 1 and table 2-1. | 4-5                   |
| A         | JP 3261043 B2 (KAWASAKI STEEL CORP.) 25 February 2002 (2002-02-25)<br>See paragraphs [0041]-[0044] and claims 1-9.                          | 1-9                   |
| A         | KR 10-2023-0030973 A (HYUNDAI STEEL COMPANY) 07 March 2023 (2023-03-07)<br>See claims 1-8.                                                  | 1-9                   |

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

\* Special categories of cited documents:

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

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“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

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“&” document member of the same patent family

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Date of the actual completion of the international search<br><b>07 March 2025</b>                                                                                                                             | Date of mailing of the international search report<br><b>10 March 2025</b> |
| Name and mailing address of the ISA/KR<br><b>Korean Intellectual Property Office<br/>Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208</b><br>Facsimile No. <b>+82-42-481-8578</b> | Authorized officer<br><br>Telephone No.                                    |

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.  
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