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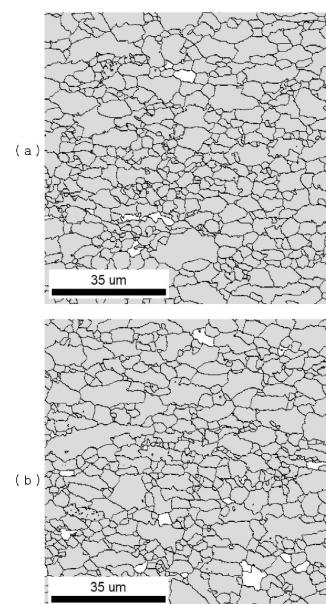
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(54) **STEEL SHEET AND MANUFACTURING METHOD THEREOF**

(57) The present invention relates to a material used for vehicle interior panels, reinforcing materials, and the like and, more specifically, to a high-strength steel sheet having excellent material uniformity and a manufacturing method thereof.

[FIG. 1]



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Description

Technical Field

5 **[0001]** The present disclosure relates to a material used for vehicle interior panels, reinforcing materials, and the like, and more particularly, to a high-strength steel sheet having excellent material uniformity and a method for manufacturing the same.

Background Art

10 **[0002]** In recent years, demand for vehicle body weight lightening, in response to stricter fuel efficiency regulations, is increasing. To this end, higher strength in a steel sheet is required, and a high strength low alloy (HSLA) steel type, which is widely used as a material for vehicle interior plates, is also required to have high strength characteristics. The HSLA steel type is characterized by having a high yield ratio which is favorable for collision characteristics and low
15 Ceq favorable for welding, and generally a 450 MPa grade based on a maximum yield strength is being widely used.

[0003] The HSLA steel type having a grade of the yield strength of 450 MPa is designed mainly as a precipitation strengthening type, and in a precipitation strengthening steel, strength is secured by production of a carbonitride using a precipitation element such as Ti, Nb, and V in a matrix composed of ferrite and pearlite. The carbonitride produces a precipitation strengthening effect by restricting movement of dislocations and also becomes a factor delaying recrystallization during annealing after cold rolling to leave unrecrystallized ferrite in a final microstructure. When the unrecrystallized ferrite is excessive, the yield strength is increased, but it becomes the main cause of material variation in a coil length direction or width direction.

[0004] Patent Document 1 discloses a steel sheet which uses recrystallized/transformed ferrite and unrecrystallized ferrite together by delaying recrystallization of ferrite using a precipitation strengthening element. As such, when a large amount of unrecrystallized ferrite exists in the steel sheet, it is favorable for securing yield strength and yield ratio, but an elongation rate is low and a material variation is large. Since unrecrystallized ferrite is used in Patent Document 1, the steel sheet reacts sensitively to process conditions, and thus, the material variation occurs significantly.

[0005] Patent Document 2 is also a document using unrecrystallized ferrite and discloses a steel sheet having improved stretch flangeability by soft ferrite and unrecrystallized ferrite. However, the steel sheet described above has a problem of, most of all, non-uniform material by coil length during manufacture of coil along with the material variation by direction, due to the inclusion of unrecrystallized ferrite. Substantially, there is a distinct difference in material among a top portion, a middle portion, and a bottom portion of coil.

[0006] Meanwhile, in the case of steel material including unrecrystallized structure, an unrecrystallization fraction formed depending on cooling conditions during cooling changes, and thus, a large material variation by the position of a steel material occurs.

(Patent Document 1) Japanese Patent Laid-Open Publication No. 2008-190032

(Patent Document 2) Japanese Patent Laid-Open Publication No. 2008-106351

Summary of Invention

Technical Problem

45 **[0007]** The present disclosure relates to a steel sheet appropriate for a vehicle interior panel, a reinforcing material, and the like, and an aspect of the present disclosure is to provide a high-strength steel sheet having excellent yield ratio and also a small material variation by position of steel, and a method for manufacturing the same.

[0008] 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 descriptions throughout the specification of the present disclosure. Solution to Problem

[0009] According to an aspect of the present disclosure, a steel sheet includes, by weight: 0.03 to 0.12% of carbon (C), 1.0 to 1.6% of manganese (Mn), 0.6% or less (excluding 0%) of silicon (Si), 0.03% or less (excluding 0%) of phosphorus (P), 0.01% or less (excluding 0%) of sulfur (S), 0.01% or less (excluding 0%) of nitrogen (N), 0.01 to 0.06% of aluminum (Al), 0.005 to 0.060% of niobium (Nb), 0.003 to 0.060% of titanium (Ti), a remainder of Fe, and
55 other unavoidable impurities.

[0010] In an example embodiment of the present disclosure, the steel sheet may include 85% or more of ferrite by area fraction and residual pearlite as a microstructure, and the ferrite may include 5% or less (including 0%) of unrecrystallized ferrite by area fraction in the entire microstructure.

[0011] As such, a steel sheet having an excellent yield ratio and an excellent material variation by a position of steel may be provided by appropriately controlling the alloy composition and the microstructure of the steel sheet.

[0012] In an example embodiment of the present disclosure, a ratio (b/a) of an average crystal grain size (b) of unrecrystallized ferrite to an average crystal grain size (a) of the recrystallized ferrite may be 0.50 or less.

[0013] In an example embodiment of the present disclosure, the unrecrystallized ferrite may have an aspect ratio (major diameter/minor diameter) of 3.0 or less.

[0014] In an example embodiment of the present disclosure, the steel sheet may further include 0.003% or less of boron (B).

[0015] In an example embodiment of the present disclosure, the steel sheet may have a yield strength of 380 MPa or more and a tensile strength of 440 MPa or more.

[0016] In an example embodiment of the present disclosure, a plating layer may be included on at least one surface of the steel sheet.

[0017] According to another aspect of the present disclosure, a method for manufacturing a steel sheet includes: preparing a steel slab having the alloy composition described above; heating the steel slab in a temperature range of 1100 to 1300°C; finish hot rolling the heated steel slab at 880°C or higher to obtain a hot-rolled steel sheet; winding the hot-rolled steel sheet in a temperature range of 400 to 650°C; pickling the wound hot-rolled steel sheet and then cold rolling the steel sheet at a cold rolling reduction rate of 40 to 80% to obtain a cold-rolled steel sheet; annealing heat treating the cold-rolled steel sheet in a temperature range of 760 to 850°C; and cooling the annealing heat treated cold-rolled steel sheet to room temperature at a cooling rate of 3°C/s or more.

[0018] In an example embodiment of the present disclosure, the cold rolling and the annealing heat treating may satisfy the following Relation 1, and when the cold rolling reduction rate is less than 70%, the following Relation 1 may be 864 or more:

[Relation 1]

$$\text{Cold rolling reduction rate} + \text{annealing temperature} > 840$$

wherein units are not considered.

[0019] In an example embodiment of the present disclosure, hot-dip galvanizing the cooled cold-rolled steel sheet in a temperature range of 440 to 480°C to obtain a hot-dip galvanized steel sheet may be further included.

[0020] In an example embodiment of the present disclosure, alloying heat treatment may be optionally further included after the hot-dip galvanizing.

Advantageous Effects of Invention

[0021] According to the present disclosure, there is an effect of providing a steel sheet which has an excellent steel material variation and a high yield ratio characteristic, and thus, is appropriate for an automotive material, in particular, an interior plate material.

Brief Description of Drawings

[0022]

FIG. 1 shows the results of EBSD measurement of the inventive example according to an example embodiment.
FIG. 2 shows the results of EBSD measurement of the comparative example according to an example embodiment.
FIG. 3 is SEM images of the inventive example and the comparative example according to an example embodiment.

Best Mode for Invention

[0023] The inventors of the present disclosure conducted an in-depth study in order to obtain a steel having a minimized material variation by position of steel, that is, excellent material uniformity, along with generally required physical properties such as strength, in providing a steel appropriate for a vehicle interior plate material.

[0024] As a result, it was confirmed that the material uniformity of a steel sheet may be improved by suppressing formation of unrecrystallized ferrite, in including ferrite as a microstructure of a steel sheet, thereby completing the present disclosure.

[0025] In particular, there is a technical significance in optimizing manufacturing conditions, in particular, cold rolling and annealing heat treatment process, along with an alloy composition, in suppressing formation of unrecrystallized ferrite in the microstructure of a steel sheet.

[0026] Hereinafter, the present disclosure will be described in detail.

[0027] The steel sheet according to an aspect of the present disclosure may include, by weight: 0.03 to 0.12% of carbon (C), 1.0 to 1.6% of manganese (Mn), 0.6% or less (excluding 0%) of silicon (Si), 0.03% or less (excluding 0%) of phosphorus (P), 0.01% or less (excluding 0%) of sulfur (S), 0.01% or less (excluding 0%) of nitrogen (N), 0.01 to 0.06% of aluminum (Al), 0.005 to 0.060% of niobium (Nb), and 0.003 to 0.060% of titanium (Ti).

[0028] Hereinafter, the reasons that the alloy composition of the steel sheet according to an aspect of the present disclosure is limited as described above will be described in detail.

[0029] Meanwhile, unless otherwise particularly stated, the content of each element is by weight and the ratios of the structure are by area.

Carbon (C): 0.03 to 0.12%

[0030] Carbon (C), which is an interstitial solid solution element, effectively contributes to securing steel strength. In addition, C is an important element for forming Ti-based and/or Nb-based precipitate with pearlite in steel, and needs to be added at or above a certain level in order to implement a microstructure to be desired in the present disclosure. In particular, in terms of securing strength targeted in the present disclosure, C may be included at 0.03% or more. However, when the content is excessive, a decrease in an elongation rate is caused, thereby increasing a possibility of causing a flexural defect and the like on a surface of a product in part working later. Thus, C may be included at 0.12% or less.

[0031] As such, C may be included at 0.03% or more, more favorably at 0.04% or more, and more favorably at 0.05% or more. In addition, C may be included at 0.12% or less, more favorably at 0.11% or less, and still more favorably at 0.10% or less.

Manganese (Mn): 1.0 to 1.6%

[0032] Manganese (Mn), which is a solid solution strengthening element, contributes to a strength increase, and also has an effect of precipitate S in steel as MnS to suppress brittleness occurrence caused by S. In order to obtain the effect, Mn may be included at 1.0% or more. However, when the content of Mn is excessive, an annealing oxide may be formed to cause a problem such as surface defects, and an elongation rate may be lowered to deteriorate processability. Thus, Mn may be included at 1.6% or less.

[0033] As such, Mn may be included at 1.0% or more, more favorably 1.1% or more, and more favorably at 1.15% or more. In addition, Mn may be included at 1.6% or less, more favorably at 1.5% or less, and still more preferably at 1.45% or less.

Silicon (Si): 0.6% or less (excluding 0%)

[0034] Silicon (Si) is an element contributing to an increase in steel strength by solid solution strengthening. However, since the intended physical properties may be secured without adding Si in the present disclosure, Si is not intentionally added.

[0035] When the content of Si is more than 0.6% in the present disclosure, plating surface characteristics are deteriorated, and thus, the upper limit may be limited to 0.6%. It may be more favorably 0.5% or less, still more favorably 0.4% or less. Meanwhile, 0% may be excluded, considering that Si is at an inevitably introduced level in the manufacturing process of steel.

Phosphorus (P): 0.03% or less (excluding 0%)

[0036] Phosphorus (P) is an element which is the most effective for securing steel strength through solid solution strengthening, without greatly damaging a drawing characteristics of steel. When P is excessively added, a brittle fracture possibility is increased to cause plate rupture of a slab during hot rolling, and also surface characteristics of a plated steel sheet may be greatly deteriorated. Therefore, the content of P may be limited to 0.03% or less. However, 0% may be excluded, considering an inevitably introduced level in the steel manufacturing process.

Sulfur (S): 0.01% or less (excluding 0%)

[0037] Sulfur (S) is an unavoidably added impurity, and in order to secure the welding characteristic of steel excel-

lently, it is favorable that the content of S is controlled to be as low as possible. In particular, since S present in steel may cause red shortness, the content may be limited to 0.01% or less considering this. However, 0% may be excluded, considering an inevitably introduced level in the steel manufacturing process.

5 Nitrogen (N): 0.01% or less (excluding 0%)

[0038] Since nitrogen (N) is also an impurity unavoidably added to steel, it is favorable to control the content to be as low as possible, but considering a steelmaking load, operating conditions, and the like, the content may be limited to 0.01% or less. Meanwhile, 0% may be excluded, considering an inevitably introduced level of N in the steel manufacturing process.

Aluminum (Al): 0.01 to 0.06%

[0039] Aluminum is an element added in order to obtain steel particle size refinement and deoxidation effects. In particular, in the present disclosure, in order to obtain an Al-killed steel in a stable state, it is preferred to include 0.01% or more of Al. When Al is excessively added, it is favorable for a strength increase by crystal grain refinement, but inclusion may be excessively formed during steelmaking casting operation to increase a possibility of deteriorating surface quality of a steel sheet and cause an increase in manufacturing costs. Thus, Al may be included at 0.06% or less.

[0040] As such, Al may be included at 0.01% or more, more favorably at 0.015% or more. In addition, Al may be included at 0.06% or less, more favorably at 0.055% or less.

Niobium (Nb): 0.005 to 0.060%

[0041] Niobium (Nb) is an element forming a carbonitride in steel, and the carbonitride formed in steel limits movement of dislocation to produce a precipitation strengthening effect and also becomes a factor delaying recrystallization during annealing after cold rolling, thereby retaining unrecrystallized ferrite in a final microstructure. Thus, in the present disclosure, it is preferred to prevent an excessive recrystallization delay effect while securing intended strength, by limiting the content of Nb.

[0042] When the content of Nb is less than 0.005%, a precipitation strengthening effect becomes insignificant, so that targeted strength may not be secured, but when the content is more than 0.060%, precipitation hardening becomes excessive, and also the recrystallization delay effect is increased, so that unrecrystallized ferrite may exist in a large amount.

35 Titanium (Ti): 0.003 to 0.060%

[0043] Titanium (Ti) is also an element which produces the same/similar effect as/to Nb. When the content of Ti is more than 0.060%, precipitation hardening becomes excessive, and also a recrystallization delay effect is increased, so that unrecrystallized ferrite may exist in a large amount, but when the content is less than 0.003%, it is difficult to obtain a precipitation strengthening effect.

[0044] Meanwhile, the steel sheet of the present disclosure may further include boron in addition to the alloy composition described above.

Boron (B): 0.003% or less

[0045] Boron (B) is an element which easily undergoes grain boundary segregation, and may be added in order to prevent secondary working brittleness which may occur when a certain amount of P is added. In addition, since hardenability is greatly improved only with addition of a small amount of B in a composite structure steel, B is favorable for securing strength. In order to obtain the effect, B may be added. However, when the content is more than 0.003%, a decrease in an elongation rate may be caused. Therefore, the content may be limited to 0.003% or less when B is added.

[0046] The remaining component of the present disclosure is iron (Fe). However, since in a common manufacturing process, unintended impurities may be unavoidably incorporated from raw materials or the surrounding environment, it may not be excluded. Since these impurities are known to any person skilled in the common manufacturing process, the entire contents thereof are not particularly mentioned in the present specification.

[0047] According to an example embodiment of the present disclosure, a steel sheet may include a ferrite phase as a main phase, and include a pearlite phase as a second phase, in a microstructure. However, the steel sheet does not exclude other structures which are unavoidably produced in the steel manufacturing process, in addition to the phases

described above, as the microstructure. As an example, the steel sheet may include a hard phase such as a bainite phase. Herein, a microstructure fraction of the steel sheet may be measured based on the total thickness of the steel sheet.

[0048] More specifically, the steel sheet may include 85% or more of ferrite by area fraction and residual pearlite as a microstructure. When the fraction of the ferrite is less than 85%, or the fraction of pearlite is more than 15%, strength of the steel sheet is excessively increased, and an elongation rate is greatly decreased, so that working characteristic may be deteriorated.

[0049] Since the lower the ferrite fraction is, the hard phase fraction of pearlite and the like is relatively increased, it may be favorable for implementing a composite structure. However, when the fraction of a hard phase such as pearlite is increased, an increase in a yield strength and a yield ratio of the steel sheet is necessarily involved, and thus, a possibility of occurrence of surface flexural defects and the like during working into parts later is increased. Thus, the fraction of ferrite is limited to 85% or more, based on the total thickness of the steel sheet.

[0050] The steel sheet according to an example embodiment of the present disclosure includes a recrystallized ferrite phase, in including a ferrite phase, and preferably, the fraction of unrecrystallized ferrite in the ferrite may be 5% by area of the entire microstructure.

[0051] That is, in an example embodiment of the present disclosure, the material uniformity of the manufactured steel sheet may be secured by suppressing production of unrecrystallized ferrite in the manufacturing process. In particular, an effect of minimizing material variation in a length direction (rolling direction) may be obtained.

[0052] More preferably, the fraction of the unrecrystallized ferrite may be less than 5% by area, more favorably 4% by area or less, and more favorably 3% by area or less, and 0% by area may be included.

[0053] In an example embodiment of the present disclosure, when unrecrystallized ferrite is included in ferrite, it is characterized by being minute in size. In particular, when the size is compared with the size of recrystallized ferrite, a ratio (b/a) of an average crystal grain size (b) of unrecrystallized ferrite to an average crystal grain size (a) of recrystallized ferrite may be 0.50 or less. As such, fine-sized unrecrystallized ferrite may act more favorably for securing intended physical properties.

[0054] In addition to this, the unrecrystallized ferrite may have an aspect ratio (or major-minor diameter ratio) of 3.0 or less. When the aspect ratio of the unrecrystallized ferrite is more than 3.0, securing of physical properties may be adversely affected due to formation of stretched ferrite. Herein, the aspect ratio shows a value obtained by dividing the major diameter by the minor diameter (major diameter/minor diameter), when the crystal grain size is converted into a circle equivalent diameter. Herein, as the value is close to 1.0, it means a spherical shape.

[0055] In an example embodiment of the present disclosure, the steel sheet may have high strength characteristics, and more preferably, may have characteristics of a yield strength of 380 MPa or more and a tensile strength of 440 MPa or more. In particular, the tensile strength may be 500 MPa or more.

[0056] Besides, the steel sheet has an excellent material uniformity characteristic, and specifically, has an effect of a minimized material variation in the length direction (rolling direction). In particular, it may have the characteristics of a difference in strength in the length direction, a difference in strength of a top portion, a middle portion, and a bottom portion of coil of 30 MPa or less.

[0057] Though it will be described in detail later, the steel sheet according to an example embodiment of the present disclosure is a cold-rolled steel sheet manufactured through a series of rolling processes, and may also include a plated steel sheet including a plating layer on at least one surface of the cold-rolled steel sheet.

[0058] Hereinafter, a method for manufacturing a steel sheet according to another aspect of the present disclosure will be described.

[0059] According to an example embodiment of the present disclosure, a steel sheet to be desired may be manufactured through processes of [steel slab heating - hot rolling - winding - cold rolling - annealing heat treatment], and the conditions for each step will be described in detail below. However, the manufacturing process described later corresponds to an example for manufacturing the steel sheet of the present disclosure.

[Steel slab heating]

[0060] A steel slab having the alloy component system described above may be prepared, and then may be heated to a temperature range of 1100 to 1300°C.

[0061] The heating process of the steel slab is a process for performing the hot rolling process described later well, and when the heating temperature is lower than 1100°C, a rolling load may occur in the subsequent hot rolling process, but when the temperature is higher than 1300°C, surface scale defects may occur.

[Hot rolling]

[0062] The steel slab heated according to the above may be hot rolled to obtain a hot-rolled steel sheet, and finish

hot rolling may be performed at 880°C or higher at this time. When the temperature is lower than 880°C during finish hot rolling, two-phase region rolling may be performed to cause structure non-uniformity.

[Winding]

[0063] The hot-rolled steel sheet may be wound. The winding may be performed in a temperature range of 400 to 650°C.

[0064] During the winding, in order to obtain a precipitation strengthening effect in a later annealing process while refining the crystal grain size, lower temperature is favorable, but when the temperature is lower than 400°C, a water film occurs on the surface of coil, so that it is difficult to secure temperature uniformity. However, when the temperature is higher than 650°C, second scale may occur to deteriorate a steel sheet surface.

[Cold rolling]

[0065] The wound hot-rolled steel sheet may be cold rolled with uncoiling to obtain a cold-rolled steel sheet. Herein, a rolling reduction rate may be controlled so that an intended thickness may be obtained, and may be controlled to 40 to 80%.

[0066] When the rolling reduction rate during the cold rolling is less than 40%, a recrystallization driving force by cold rolling is insufficient, so that the recrystallization of ferrite is not completed, and the unrecrystallized ferrite structure excessively remains. However, when it is more than 80%, a rolling roll load becomes severe to deteriorate the shape.

[0067] More favorably, the cold rolling may be performed at a cold rolling reduction rate of 50% or more and 70% or less.

[0068] In an example embodiment of the present disclosure, before performing the cold rolling, a pickling process may be further performed in order to remove surface scale of the wound hot-rolled steel sheet. Since the pickling process depends on common conditions, the conditions are not particularly defined in the present disclosure.

[Annealing heat treatment]

[0069] The cold-rolled steel sheet may be subjected to an annealing heat treatment.

[0070] During the annealing heat treatment, it may be performed in a temperature range of 760 to 850°C so that the recrystallization of a steel sheet is sufficiently performed. When the temperature is lower than 760°C during the annealing heat treatment, unrecrystallized ferrite may excessively remain after completing annealing, but when the temperature is higher than 850°C, crystal grains are coarsened, so that a targeted strength level may not be secured.

[0071] Meanwhile, when the rolling reduction rate in the previously performed cold rolling process is low, in particular, when a rolling reduction rate of 40% or more and less than 70% is applied, a recrystallization driving force is relatively low, and thus, the temperature may be set to 800°C or higher, more preferably 830°C or higher so that recrystallization is sufficiently performed in the subsequent annealing heat treatment process.

[0072] In particular, according to an example embodiment of the present disclosure, in performing the cold rolling and annealing heat treatment, the following [Relation 1] is satisfied, but when the rolling reduction rate during the cold rolling is less than 70%, it is preferred that the following Relation 1 is 864 or more.

[Relation 1]

$$\text{Cold rolling reduction rate} + \text{annealing temperature} > 840$$

wherein units are not considered.

[Cooling]

[0073] The cold-rolled steel sheet which has completed the annealing heat treatment according to the above may be cooled to room temperature. Herein, it may be performed at a cooling rate of 3°C/s or more. When the cooling rate is less than 3°C/s, a hard phase (low-temperature transformation phase) may be formed to excessively increase the fraction.

[0074] The upper limit of the cooling rate is not particularly limited and may be appropriately defined depending on equipment specifications.

[0075] An intended steel sheet may be obtained through the series of processes described above. In particular, since sufficient recrystallization is performed during the cold rolling and annealing heat treatment processes, a steel

sheet having a minimized unrecrystallized ferrite fraction may be obtained. Thus, the steel sheet of the present disclosure may have excellent material uniformity with high strength.

[0076] Meanwhile, a plated steel sheet may be manufactured by performing a plating process on the cold-rolled steel sheet manufactured above. The plating process herein is a hot-dip galvanization process and will be described in detail below.

[Hot-dip galvanization]

[0077] The annealed cold-rolled steel sheet is hot-dip galvanized in a continuous hot-dip galvanizing line, thereby obtaining a zinc-plated steel sheet having a zinc-based plating layer formed on at least one surface of the cold-rolled steel sheet.

[0078] The hot-dip galvanization may be performed by dipping the annealed cold-rolled steel sheet in a plating bath having zinc as a main component, and the components in the plating bath are not particularly limited and may depend on common conditions. As an example, the hot-dip galvanization may be performed in a temperature range of 440 to 480°C.

[0079] After performing the hot-dip galvanization, an alloying heat treatment process may be further performed, and this process may also be performed under common conditions.

Mode for Invention

[0080] 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 rights of the present disclosure. The reason is that the rights scope of the present disclosure is determined by the matters described in the claims and reasonably inferred therefrom.

(Examples)

Conventional Examples

[0081] A cold-rolled steel sheet was manufactured under the conventional process conditions, and then mechanical properties of each cold-rolled steel sheet were evaluated. At this time, a steel slab of steel type C shown in the following Table 2 was prepared, and the reheating temperature, the winding temperature, the cold rolling reduction rate, the annealing temperature, and the cooling rate were applied to the steel slab, as shown in the following Table 1, thereby manufacturing a cold-rolled steel sheet. Meanwhile, during hot rolling after reheating of the steel slab, finish hot rolling was performed at 900°C.

[0082] The yield strength and the tensile strength of each of the manufactured cold-rolled steel sheets were measured, and the measurement methods were identically applied as shown below.

[Table 1]

Classification	Process conditions					Mechanical properties	
	Reheating temperature (°C)	Winding temperature (°C)	Cold rolling reduction rate (%)	Annealing temperature (°C)	Cooling rate (°C)	Yield strength (MPa)	Tensile strength (MPa)
Conventional Example 1	1200	450	60	770	3	534	598
Conventional Example 2	1200	600	60	770	3	490	567
Conventional Example 3	1250	550	60	770	3	534	663
Conventional Example 4	1200	450	50	770	3	576	643
Conventional Example 5	1250	560	50	770	3	565	642

(continued)

Classification	Process conditions					Mechanical properties	
	Reheating temperature (°C)	Winding temperature (°C)	Cold rolling reduction rate (%)	Annealing temperature (°C)	Cooling rate (°C)	Yield strength (MPa)	Tensile strength (MPa)
Conventional Example 6	1150	500	50	770	3	562	635

[0083] As shown in Table 1, it may be confirmed that the yield strength tended to increase as the reheating temperature was higher and the winding temperature was lower. This was due to the fact that a precipitation phase was suppressed as much as possible in the hot rolling process, and the precipitation phase was finely distributed in the cold rolling and annealing processes. In addition, by performing annealing at a lower temperature, strength was largely high due to the remaining of an unrecrystallized structure. Thus, Conventional Examples 1 to 6 are expected to cause a material variation in the length direction in a coil state.

Inventive Examples and Comparative Examples

[0084] Slabs having the alloy composition of the following Table 2 were prepared, and then each slab was reheated to 1200°C, hot rolled at a finish rolling temperature of 900 to 950°C, and wound to obtain a hot-rolled steel sheet. Thereafter, the steel sheet was cold rolled at a reduction rate of 54%, and continuously annealing heat treated to manufacture a cold-rolled steel sheet. At this time, several cold-rolled steel sheets were hot-dip galvanized to manufacture a plated steel sheet. Each process conditions is shown in the following Table 3.

[0085] The cold-rolled steel sheets and the plated steel sheets manufactured according to the above were subjected to a tensile test in a rolling direction, in accordance with the standards of JIS-5, thereby measuring the physical properties of yield strength (YS), tensile strength (TS), and elongation rate (EI).

[0086] In addition, in order to measure the microstructure of each steel sheet, the specimen obtained according to JIS-5 was observed by an optical microscope and a scanning electron microscope (SEM) to measure the fraction of each phase, and among them, the fraction of unrecrystallized ferrite was measured using electron back scattering diffraction (EBSD).

[0087] Further, the average size of ferrite was obtained by determining each of the average crystal grain size (a) of recrystallized ferrite and the average crystal grain size (b) of unrecrystallized ferrite, and then calculating the b/a value. At this time, an application was used in the results measured using SEM to measure each crystal grain size distribution, and then the average value was calculated. Each result is shown in the following Table 4.

[Table 2]

Steel type	Alloy composition (wt%)								
	C	Si	Mn	Al	P	S	N	Nb	Ti
A	0.085	0.21	1.10	0.048	0.019	0.002	0.003	0.036	0.005
B	0.080	0.20	1.09	0.047	0.019	0.002	0.003	0.034	0.005
C	0.082	0.30	1.35	0.043	0.019	0.002	0.004	0.040	0.005
D	0.082	0.30	1.34	0.039	0.019	0.002	0.004	0.041	0.005
E	0.125	0.02	1.35	0.038	0.020	0.002	0.003	0.045	0.045
F	0.122	0.01	1.27	0.037	0.020	0.002	0.005	0.044	0.048

[Table 3]

Steel type	Reheating temperature (°C)	Winding temperature (°C)	Cold rolling reduction rate (%)	Annealing temperature (°C)	Relation 1	Cooling rate (°C/s)	Classification
A	1200	560	54	810	864	3	Inventive Example 1

(continued)

Steel type	Reheating temperature (°C)	Winding temperature (°C)	Cold rolling reduction rate (%)	Annealing temperature (°C)	Relation 1	Cooling rate (°C/s)	Classification
B	1220	450	54	810	864	3	Inventive Example 2
C	1200	560	54	830	884	3	Inventive Example 3
D	1220	450	54	820	874	3	Inventive Example 4
A	1180	560	54	830	884	3	Inventive Example 5
E	1200	560	55	810	865	3	Comparative Example 1
F	1200	450	55	810	865	3	Comparative Example 2
A	1200	560	54	780	834	3	Comparative Example 3
C	1200	560	54	770	824	3	Comparative Example 4

[Table 4]

Classification	Microstructure						Mechanical properties					
	Fraction (% by area)			F average size			Tensile strength (MPa)			Yield strength (MPa)		
	F	P	Unrecrystallized F	Recrystallized F(a)	Unrecrystallized F(b)	b/a	Top portion	Middle portion	Bottom portion	Top portion	Middle portion	Bottom portion
Inventive Example 1	95	5	0~0.9	6.5	2.0	0.31	534	542	559	431	445	421
Inventive Example 2	94	6	0~1.3	6.4	2.1	0.33	531	538	554	434	441	428
Inventive Example 3	94	6	0~2.1	6.2	2.4	0.39	556	550	565	452	450	443
Inventive Example 4	93	7	0~2.4	5.8	2.6	0.45	556	555	557	460	458	462
Inventive Example 5	95	5	0~0.7	6.5	1.9	0.29	536	528	532	404	398	386
Comparative Example 1	83	17	40~60	5.3 4.7	4.3 6.3	0.81 1.34	658	615	681	572	530	613
Comparative Example 2	82	18	40~60	5.4 4.8	4.3 6.1	0.80 1.27	667	632	672	580	545	592
Comparative Example 3	94	6	10~40	5.8 5.4	3.6 4.3	0.62 0.80	552	528	559	453	415	469
Comparative Example 4	93	7	30~50	5.4 5.3	4.1 6.0	0.76 1.13	592	558	560	487	454	456
F: Ferrite, P: Pearlite In Table 4, ferrite refers to a total ferrite fraction including unrecrystallized ferrite.												

(continued)

Classification	Microstructure						Mechanical properties					
	Fraction (% by area)			F average size			Tensile strength (MPa)			Yield strength (MPa)		
	F	P	Unrecrystallized F	Recrystallized F(a)	Unrecrystallized F(b)	b/a	Top portion	Middle portion	Bottom portion	Top portion	Middle portion	Bottom portion
	In addition, since unrecrystallized ferrite has different fractions depending on the measurement positions (top, middle, and bottom), it was obtained in the range based on the minimum fraction and the maximum fraction. The average size of ferrite (F) refers to a ratio (b/a) of the average crystal grain size (b) of unrecrystallized ferrite to the average crystal grain size (a) of recrystallized ferrite, and the unit of each size is μm. At this time, since the comparative examples showed large difference in the unrecrystallization fraction between the top portion and the middle portion, the average size of ferrite each portion (upper: top portion, lower: middle portion) was calculated and is shown.											

[0088] As shown in Tables 2 to 4, Inventive Examples 1 to 5 which satisfied all of the alloy compositions and the manufacturing conditions suggested in the present disclosure included a ferrite phase as a main phase in the microstructure, but the fraction of the unrecrystallized ferrite was minimized to 5% or less. In particular, it was confirmed that the unrecrystallized ferrite was formed in fine sizes. Thus, the material uniformity in the length direction of the steel sheet was excellent, and a targeted strength level was confirmed.

[0089] However, in Comparative Examples 1 and 2 in which the alloy composition was out of the scope of the present disclosure and in Comparative Examples 3 and 4 in which the alloy composition was satisfied, but among the manufacturing conditions, Relation 1 was not satisfied, the fraction of the unrecrystallized ferrite phase was excessive, the size was also coarse, and thus, the material uniformity in the length direction of the steel sheet was not able to be secured. In particular, a difference in strength was more than 30 MPa, and there was even a portion having the difference of up to 54 MPa, based on the strength value of the middle portion. That is, as expected in the conventional examples, it was confirmed that the material variation in the length direction occurs in Comparative Examples 3 and 4 which were substantially out of the scope of Relation 1.

[0090] Meanwhile, though it is not described together, Inventive Examples 1 to 5 had the aspect ratio of unrecrystallized ferrite of 3.0 or less, and it was confirmed representatively from the microstructure photograph of Inventive Example 4 shown in FIG. 1.

[0091] However, Comparative Examples 1 to 4 had a large amount of unrecrystallized ferrite having the aspect ratio of more than 3.0, and it was confirmed representatively from the microstructure photograph of Comparative Example 3 shown in FIG. 2.

[0092] FIG. 1 shows the EBSD results of observing the microstructure of Inventive Example 4, and it was confirmed that recrystallization was completed in both the middle portion (a) and the top portion (b).

[0093] It was found therefrom that as a result of measuring strength of the specimens collected from the top portion and the middle portion, the yield strength and the tensile strength were nearly uniform, as shown in Table 3. In addition, it was confirmed that the aspect ratio of the unrecrystallized ferrite was 3.0 or less.

[0094] FIG. 2 shows the EBSD Results of observing the microstructure of Comparative Example 3, and it was confirmed that a large amount of the unrecrystallized structure remained without completing recrystallization in both the middle portion (a) and the top portion (b). In particular, the unrecrystallization fraction was measured as 10.9% in the middle portion and measured as 32.9% in the top portion. In addition, it was confirmed that the aspect ratio of the unrecrystallized ferrite was more than 3.0.

[0095] As such, a difference in yield strength occurred due to the difference in unrecrystallization fraction by position of coil, and the difference was about 38 MPa. At this time, since the yield strength was increased in the region having a higher unrecrystallization fraction, non-uniformity occurred locally to cause a large material variation.

[0096] FIG. 3 shows the SEM results obtained by observing Comparative Example 4 (a) and Inventive Example 3 (b), and it was confirmed that Comparative Example 4 in which the annealing process was performed at 770°C had about 50% by area of the unrecrystallization structure. However, in Inventive Example 3 in which the annealing process was performed at 830°C, the unrecrystallization structure was observed within 5% by area.

[0097] At this time, as confirmed in (a) of FIG. 3, it was observed that the crystal grains of the unrecrystallization structure existed in the stretched form in the rolling direction, and a transformation structure remained in the grains. However, as shown in (b) of FIG. 3, the structure in which the recrystallization was almost completed existed in a shape close to spherical.

Claims

1. A steel sheet comprising, by weight: 0.03 to 0.12% of carbon (C), 1.0 to 1.6% of manganese (Mn), 0.6% or less (excluding 0%) of silicon (Si), 0.03% or less (excluding 0%) of phosphorus (P), 0.01% or less (excluding 0%) of sulfur (S), 0.01% or less (excluding 0%) of nitrogen (N), 0.01 to 0.06% of aluminum (Al), 0.005 to 0.060% of niobium (Nb), 0.003 to 0.060% of titanium (Ti), a remainder of Fe, and other unavoidable impurities,

wherein 85% or more of ferrite by area fraction and residual pearlite are included as a microstructure, the ferrite is formed of recrystallized ferrite and unrecrystallized ferrite, and the area fraction of the unrecrystallized ferrite in the entire microstructure is 5% or less (including 0%).

2. The steel sheet of claim 1, wherein a ratio (b/a) of an average crystal grain size (b) of unrecrystallized ferrite to an average crystal grain size (a) of the recrystallized ferrite is 0.50 or less.

3. The steel sheet of claim 1, wherein the unrecrystallized ferrite has an aspect ratio (major diameter/minor diameter) of 3.0 or less.

4. The steel sheet of claim 1, further comprising 0.003% or less by weight of boron (B).

5. The steel sheet of claim 1, wherein the steel sheet has a yield strength of 380 MPa or more and a tensile strength of 440 MPa or more.

6. The steel sheet of claim 1, wherein a plating layer is included on at least one surface of the steel sheet.

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

preparing a steel slab including, by weight: 0.03 to 0.12% of carbon (C), 1.0 to 1.6% of manganese (Mn), 0.6% or less (excluding 0%) of silicon (Si), 0.03% or less (excluding 0%) of phosphorus (P), 0.01% or less (excluding 0%) of sulfur (S), 0.01% or less (excluding 0%) of nitrogen (N), 0.01 to 0.06% of aluminum (Al), 0.005 to 0.060% of niobium (Nb), 0.003 to 0.060% of titanium (Ti), a remainder of Fe, and other unavoidable impurities;

heating the steel slab in a temperature range of 1100 to 1300°C;

finish hot rolling the heated steel slab at 880°C or higher to obtain a hot-rolled steel sheet;

winding the hot-rolled steel sheet in a temperature range of 400 to 650°C;

pickling the wound hot-rolled steel sheet and then cold rolling the steel sheet at a cold rolling reduction rate of 40 to 80% to obtain a cold-rolled steel sheet;

annealing heat treating the cold-rolled steel sheet in a temperature range of 760 to 850°C; and

cooling the annealing heat treated cold-rolled steel sheet to room temperature at a cooling rate of 3°C/s or more,

wherein the cold rolling and the annealing heat treating satisfy the following Relation 1, and when the cold rolling reduction rate is less than 70%, the following Relation 1 is 864 or more:

[Relation 1]

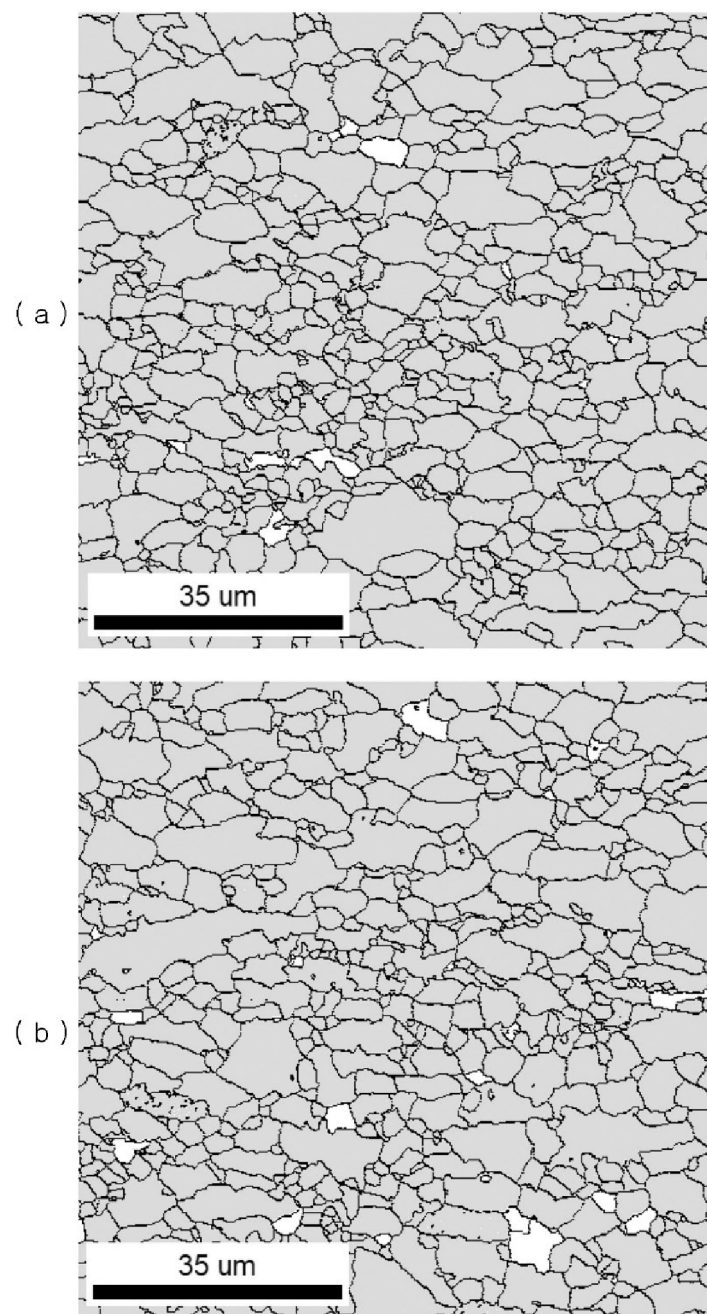
Cold rolling reduction rate + annealing temperature > 840

wherein units are not considered.

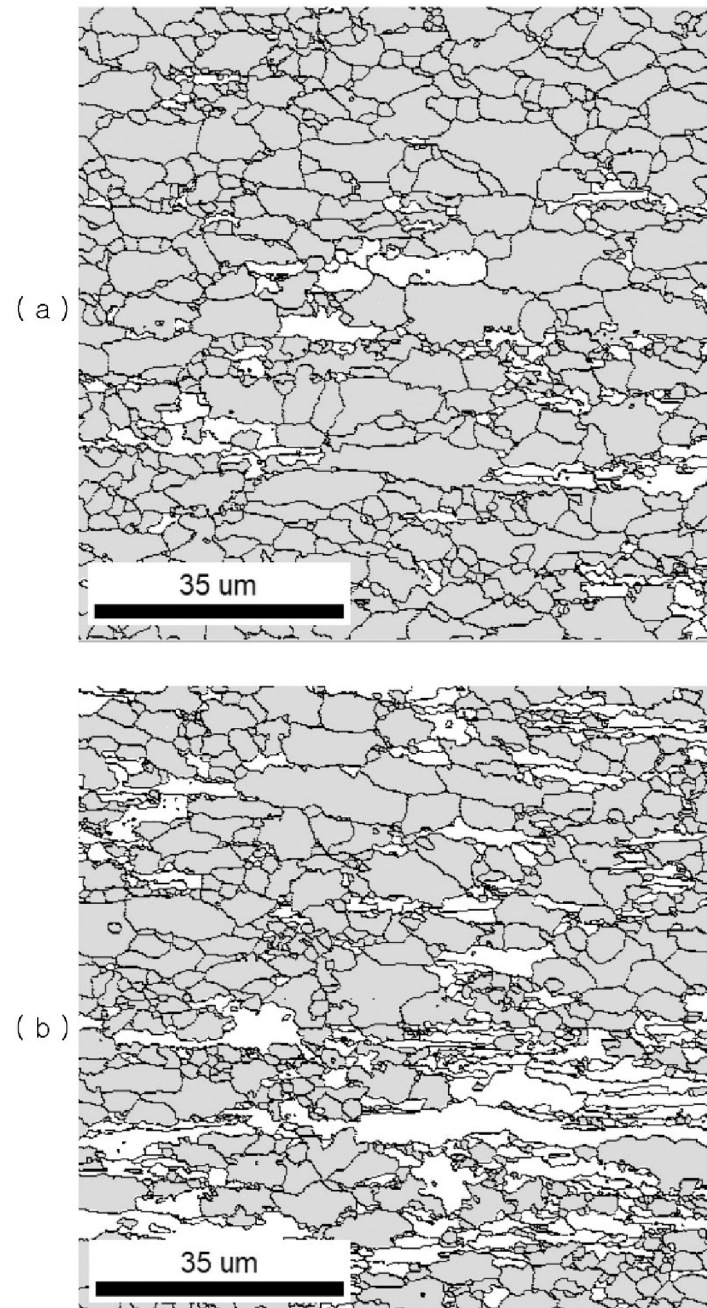
8. The method for manufacturing a steel sheet of claim 7, further comprising: hot-dip galvanizing the cooled cold-rolled steel sheet in a temperature range of 440 to 480°C to obtain a hot-dip galvanized steel sheet.

9. The method for manufacturing a steel sheet of claim 8, further comprising: after the hot-dip galvanizing, optionally performing an alloying heat treatment.

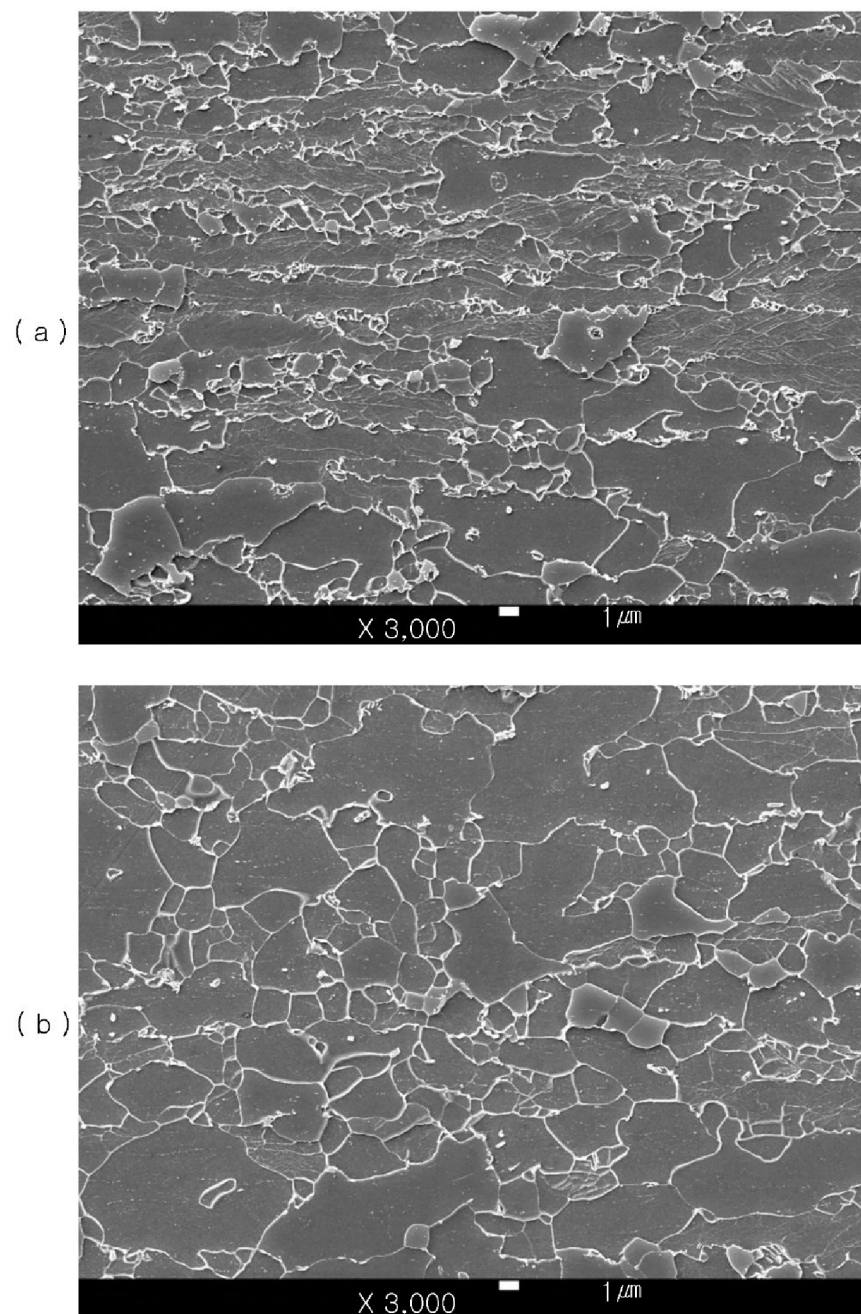
[FIG. 1]



[FIG. 2]



[FIG. 3]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/018814

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; **C22C 38/02**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/12**(2006.01)i; **C22C 38/14**(2006.01)i;
C21D 8/02(2006.01)i; **C21D 9/46**(2006.01)i; **C23C 2/06**(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 38/04(2006.01); B21B 3/00(2006.01); B22D 11/124(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01);
C22C 38/12(2006.01); C22C 38/58(2006.01); C22C 38/60(2006.01)

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

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

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

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

eKOMPASS (KIPO internal) & keywords: 강판(steel sheet), 페라이트(ferrite), 펄라이트(perlite), 보론(boron), 열간압연(hot rolled), 냉간압연(cold rolled), 소둔(annealing), 용융아연도금(hot dip galvanize), 냉각(cooling), 재결정(recrystallization)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2022-0024957 A (JFE STEEL CORPORATION) 03 March 2022 (2022-03-03) See paragraphs [0090], [0092], [0094]-[0096], [0100], [0122]-[0124], [0140], [0142] and [0177], claims 1, 3 and 8 and tables 2-3.	1-9
A	KR 10-2021-0123371 A (NIPPON STEEL CORPORATION) 13 October 2021 (2021-10-13) See paragraphs [0206]-[0212] and claims 1 and 8.	1-9
A	JP 2001-303180 A (KAWASAKI STEEL CORP.) 31 October 2001 (2001-10-31) See paragraphs [0066]-[0067] and claim 1.	1-9
A	JP 2018-016873 A (KOBELITE LTD.) 01 February 2018 (2018-02-01) See paragraphs [0065]-[0066] and claim 1.	1-9
A	US 2018-0363082 A1 (TATA STEEL LHMUIDEN B.V.) 20 December 2018 (2018-12-20) See paragraph [0114] and claim 1.	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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“O” document referring to an oral disclosure, use, exhibition or other means

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

18 February 2025

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Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/018814

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