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(71) Applicant: **POSCO Co., Ltd**
Gyeongsangbuk-do 37859 (KR)

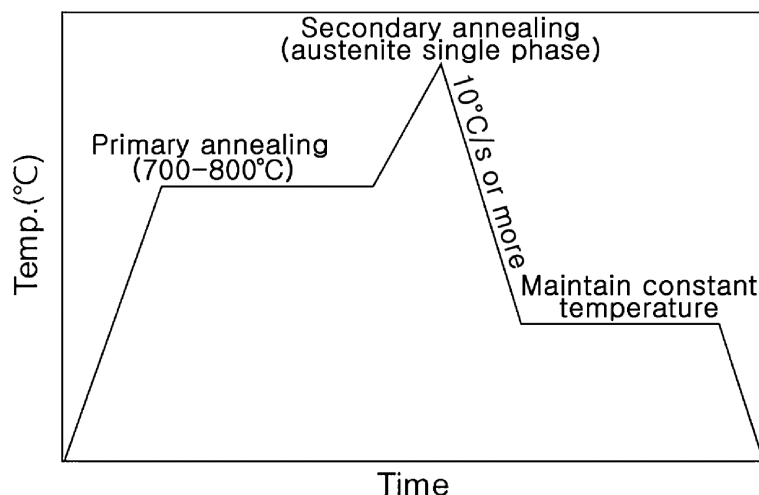
(72) Inventors:
• **KOO, Min-Seo**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **KIM, Eun-Young**
Gwangyang-si, Jeollanam-do 57807 (KR)

(74) Representative: **Meissner Bolte Partnerschaft**
mbB
Patentanwälte Rechtsanwälte
Postfach 86 06 24
81633 München (DE)

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

(57) One aspect of the present invention provides an ultra-high strength cold-rolled steel sheet having excellent elongation and a manufacturing method thereof.

[Fig.1]



EP 4 826 062 A1

Description

Technical Field

[0001] The present disclosure relates to a cold-rolled steel sheet and a manufacturing method thereof.

Background Art

[0002] In the automobile industry, the purposes of improved fuel efficiency, body stability for passenger protection, and weight lightening are being highlighted, together with a gradual increase in carbon dioxide regulations. In order to achieve the purpose, the use of an ultra-high strength steel sheet for cold stamping having a tensile strength of a 1.5 GPa grade or higher, as compared with high-strength steel used in existing automotive components, and the development thereof is increasing.

[0003] However, since a cold-rolled steel sheet has a relationship in which when strength increases, elongation decreases (that is, in an inverse relationship), its formability is poor, and thus, its application as a material for cold stamping is generally very limited.

[0004] In order to secure excellent strength and elongation intended to solve the above problem, an advanced high strength steel such as a dual-phase steel (dual steel) and transformation induced plasticity steel (TRIP steel) as a composite structure steel introducing a low-temperature transformation phase into a soft matrix is being employed as an automobile body member.

[0005] Meanwhile, in terms of weight reduction for improving fuel efficiency, strength improvement relative to a thickness decrease rate is demanded, while demand for a cold-rolled steel sheet having better elongation and formability is increasing for being applied to a vehicle member. However, an advanced high strength steel having a strength of 1 GPa or more has poor elongation and high-burring property (hole expansion ratio: HER) due to occurrence of a local interphase hardness difference.

[0006] In order to overcome such issues, an ultra-high strength steel (UHSS) comprised of only bainite and/or martensite which is/are a low-temperature transformation phase has been developed. The ultra-high strength steel generally has low bendability, but is used as parts which may be formed by roll forming.

[0007] Since the use of high strength steel as parts is increasing, in order to satisfy various characteristics of the parts, the needs for ultra-high strength steel having high ductility and a manufacturing method thereof are increasing. However, a technology level which may meet the requirements for a steel sheet having a tensile strength of a 1.5 GPa grade or higher and high ductility and a manufacturing method thereof have not been developed.

(Patent Document 1) Korean Patent Laid-Open Publication No. 10-2017-7022118

(Patent Document 2) Japanese Patent Laid-Open Publication No. 2017-145469

Summary of Invention

Technical Problem

[0008] An aspect of the present disclosure is to provide an ultra-high strength cold-rolled steel sheet having an excellent elongation and a manufacturing method thereof.

[0009] An object of the present disclosure is not limited to the above description. Additional objects of the present disclosure are described throughout the specification, and any person with ordinary skill in the art to which the present disclosure pertains has no difficulty in understanding of the additional object of the present disclosure from the description in the specification of the present disclosure.

Solution to Problem

[0010] According to an aspect of the present disclosure, a cold-rolled steel sheet is provided. The cold-rolled steel sheet includes, by weight: 0.2 to 0.4% of C, 1.0 to 2.0% of Si, 2.5 to 5.0% of Mn, 0.1% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.01 to 0.1% of Al, 0.01% or less (excluding 0%) of N, 0.005% or less (excluding 0%) of B, 0.01 to 0.04% of Ti, a remainder of Fe, and unavoidable impurities, wherein the cold-rolled steel sheet includes, by area: 10 to 30% of retained austenite and 10 to 90% of the sum of bainite and martensite, as a microstructure, and a value of the following Relationship 1 is 0.25 to 1.5:

[Relationship 1]

$$(Mn_high - Mn_low) / Mn_base$$

wherein Mn_high is an average concentration of Mn in a region in which a content of Mn in the microstructure is at least 1% higher than an average content of Mn at a t/4 point in the thickness direction of the cold-rolled steel sheet, Mn_low is an average concentration of Mn in a region in which a content of Mn in the microstructure is at least 1% lower than the average content of Mn at the t/4 point in the thickness direction of the cold-rolled steel sheet, and Mn_base is the average content of Mn at the t/4 point in the thickness of the cold-rolled steel sheet.

[0011] In addition, in the cold-rolled steel sheet described above, an area fraction of the bainite may be 30 to 60% based on the total fraction of the microstructure.

[0012] In addition, in one of the cold-rolled steel sheets described above, an area fraction of the martensite may be 10 to 60% based on the total fraction of the microstructure.

[0013] In addition, one of the cold-rolled steel sheets described above may further include, by weight: one or more selected from 0.1% or less of Cr, 0.1% or less of Mo, and 0.1% or less of Nb.

[0014] In addition, one of the cold-rolled steel sheets described above may have a tensile strength of 1500 MPa or more and an elongation of 10% or more.

[0015] In addition, one of the cold-rolled steel sheets described above may have a yield strength of 1000 MPa or more.

[0016] According to another aspect of the present disclosure, a manufacturing method of a cold-rolled steel sheet is provided. The method may include: reheating a slab including, by weight: 0.2 to 0.4% of C, 1.0 to 2.0% of Si, 2.5 to 5.0% of Mn, 0.1% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.01 to 0.1% of Al, 0.01% or less (excluding 0%) of N, 0.005% or less (excluding 0%) of B, 0.01 to 0.04% of Ti, a remainder of Fe, and unavoidable impurities; hot rolling the reheated slab to obtain a hot-rolled steel sheet; winding the hot-rolled steel sheet; cold rolling the wound hot-rolled steel sheet to obtain a cold-rolled steel sheet; performing primary annealing of maintaining the cold-rolled steel sheet at a primary annealing temperature of 700 to 800°C for 10 minutes to 24 hours; performing a secondary annealing of maintaining the primarily annealed cold-rolled steel sheet at a secondary annealing temperature at or above an austenite single phase region for a period of time of more than 0 seconds and 10 seconds or less; cooling the secondarily annealed cold-rolled steel sheet to a cooling end temperature of 280 to 480°C; and maintaining the cooled cold-rolled steel sheet at the cooling end temperature for 5 minutes to 5 hours.

[0017] In addition, in the method described above, the secondary annealing may be performed by heating to the secondary annealing temperature at an average heating rate of 2°C/s or more.

[0018] In addition, in one of the methods described above, the cooling may be performed by cooling to the cooling end temperature at an average cooling rate of 10°C/s or more.

[0019] In addition, in one of the methods described above, the reheating may be performed at 1,100 to 1,300°C, and the obtaining of the hot-rolled steel sheet may be performed by hot rolling the reheated slab at 800 to 1,000°C.

[0020] In addition, in one of the methods described above, the winding may be performed at 400 to 700°C, and the obtaining of the cold-rolled steel sheet may be performed by cold rolling the wound hot-rolled steel sheet at a reduction rate of 20 to 75%.

Advantageous Effects of Invention

[0021] According to the present disclosure, an elongation of 10% or more may be secured while having an ultra-high strength of 1.5 GPa or more.

[0022] In addition, according to the present disclosure, an ultra-high strength cold-rolled steel sheet having an excellent elongation may be appropriately used in cold stamping.

[0023] In addition, according to the present disclosure, by distributing the concentration of Mn in the microstructure, transformation of a bainite phase is promoted to secure austenite stability, and thus, retained austenite may be secured at room temperature to provide an ultra-high strength steel having an excellent elongation.

[0024] 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 example embodiments in the present disclosure.

Brief Description of Drawings

[0025] Brief description of each drawing will be provided in order to sufficiently understand the drawings cited in the detailed description of the present disclosure.

FIG. 1 is a schematic diagram showing a manufacturing method of a cold-rolled steel sheet according to an example embodiment of the present disclosure.

FIG. 2 is a photograph in which the microstructure of the cold-rolled steel sheet of Inventive Example 3 according to an example embodiment of the present disclosure is observed.

Best Mode for Invention

[0026] Hereinafter, the preferred example embodiments in the present disclosure will now be described in detail. However, the example embodiments in the present disclosure may be modified in many different forms, and the terms used in the present specification are for describing the present disclosure and are not intended to limit the present disclosure. In addition, a singular form used in the present specification includes a plural form also, unless the relevant definition has a clearly opposite meaning thereto.

[0027] In the present specification, the term "comprising" is used to indicate further inclusion of other constituent elements rather than exclusion of other constituent elements, unless otherwise particularly stated.

[0028] In addition, unless otherwise defined in the specification of the present disclosure, % unit refers to wt%.

[0029] Unless otherwise defined, all terms including technical terms and scientific terms used in the present specification have the same meaning as commonly understood by a person with ordinary skill in the art to which the present disclosure pertains. Pre-defined terms are interpreted as being consistent with the relevant technical literature and the disclosure herein.

[0030] First, an alloy composition of the cold-rolled steel sheet according to an example embodiment of the present disclosure will be described. The content of the alloy composition is wt%, unless otherwise stated.

Carbon (C): 0.2 to 0.4%

[0031] Carbon (C) may include for securing strength and hardenability. When the content of C is less than 0.2%, it may be difficult to secure a tensile strength of a 1.5 GPa grade or higher. In addition, when the content of C is more than 0.4%, strength is excessively increased as compared with a level to be desired to deteriorate an elongation or increase a potential to cause brittle fracture and cause inferiority of spot weldability. As the content of C is higher, a degree of carbide formation is increased during production of martensite, and thus, the upper limit of the content of C may be appropriately adjusted. That is, the content of C may be 0.2 to 0.4%, more specifically 0.20 to 0.40%, and still more specifically 0.22 to 0.35%.

Silicon (Si): 1.0 to 2.0%

[0032] Silicon (Si) is added as a deoxidant in a steel making process and may be included for suppressing solid solution strengthening and carbide production. In addition, Si may play role in securing retained austenite at room temperature by uniformly dispersion a microstructure during annealing or increasing austenite stability during cooling. When the content of Si is less than 1.0%, it is difficult to sufficiently secure the effects described above, and thus, it may be difficult to secure the elongation to be desired. When the content of Si is more than 2.0%, Si-based oxides may be excessively produced on the surface of a steel sheet during hot rolling to cause surface defects during cold rolling. In addition, when the content of Si is more than 2.0%, the non-resistance of the finally manufactured cold-rolled steel sheet may be excessively increased to deteriorate spot weldability. That is, the Content of Si may be 1.0 to 2.0%, specifically 1.00 to 2.00%, more specifically 1.05 to 1.90%, and still more specifically 1.10 to 1.75%.

Manganese (Mn): 2.5 to 5.0%

[0033] Manganese (Mn), which is an element for stabilizing austenite, may secure hardenability of martensite and play a role in suppressing production of ferrite during annealing after cold rolling. When the content of Mn is less than 2.5%, martensite hardenability may be secured, but occurrence of a Mn concentration gradient in a cold-rolled steel sheet becomes difficult, so that it may be difficult to secure a microstructure depending on a Mn concentration difference to be desired in the present disclosure. In addition, when the content of Mn is more than 5.0%, strength is excessively increased, or a Mn band in base iron may occur in the thickness direction from the steel making and continuous casting operations, and thus, collision resistance may be reduced. That is, the content of Mn may be 2.5 to 5.0%, more specifically 2.7 to 4.5%, and still more specifically 3.0 to 4.12%.

Phosphorus (P): 0.1% or less (excluding 0%)

[0034] Phosphorus (P) is an element included as an impurity in steel. When the content of P is more than 0.1%,

weldability may be deteriorated due to P segregation, and also, potential to cause steel brittleness may be increased. That is, the content of P may be 0.1% or less, more specifically 0.03% or less, and still more specifically 0.02% or less. Meanwhile, 0% may be excluded from the lower limit of the P content, considering the case in which P is inevitably included (that is, more than 0%). More specifically, the lower limit of the P content may be 0.003%, and still more specifically 0.005%.

Sulfur (S): 0.03% or less (excluding 0%)

[0035] Sulfur (S) is an impurity element which is inevitably added to steel. When the content of S is more than 0.03%, precipitates formed due to the precipitation of MnS during a hot rolling process are not completely decomposed during annealing, resulting in a decrease in ductility of the finally manufactured cold-rolled steel sheet or deterioration of weldability. That is, the content of S may be 0.03% or less, more specifically 0.02% or less, and still more specifically 0.005% or less. Meanwhile, 0% may be excluded from the lower limit of the S content, considering the case in which S is inevitably included (that is, more than 0%). More specifically, the lower limit of the S content may be 0.001%, and still more specifically 0.002%.

Aluminum (Al): 0.01 to 0.1%

[0036] Aluminum (Al) may be added for removing oxygen in molten steel in a steel making process and may remove impurity elements in steel. In addition, Al may play a role in suppressing carbide production and contribute to C stabilization in austenite to improve the elongation of a steel sheet. When the content of Al is less than 0.01%, it may be difficult to sufficiently secure the effects described above. In addition, when the content of Al is more than 0.1%, cracks may occur in the surrounding area due to excessive precipitation of AlN and defects in products may be caused. That is, the content of Al may be 0.01 to 0.1%, specifically 0.01 to 0.10%, more specifically 0.01 to 0.08%, and still more specifically 0.02% to 0.06%.

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

[0037] Nitrogen (N) is an impurity element in steel. When the content of N is more than 0.01%, a risk of cracking during continuous casting may be excessively increased by AlN formation. That is, the content of N may be 0.01% or less, specifically 0.010% or less, more specifically 0.009% or less, and still more specifically 0.008% or less. Meanwhile, 0% may be excluded from the lower limit of the N content, considering the case in which N is inevitably included (that is, more than 0%). More specifically, the lower limit of the N content may be 0.004%, and still more specifically 0.007%.

Boron (B): 0.005% or less (excluding 0%)

[0038] Boron (B) is an element which is favorable for suppression of ferrite phase transformation during annealing, and may improve hardenability of martensite through grain boundary strengthening and solid solution strengthening. When the content of B is more than 0.005%, $\text{Fe}_{23}(\text{B,C})_6$ which is a B-based precipitate phase is formed in the austenite grain boundary, and thus, brittle fracture may be caused in a hot-rolled state. That is, the content of B may be 0.005% or less, more specifically 0.004% or less, and still more specifically 0.003% or less. Meanwhile, 0% may be excluded from the lower limit of the B content, considering the case in which B is inevitably included (that is, more than 0%). More specifically, the lower limit of the B content may be 0.001%.

Titanium (Ti): 0.01 to 0.04%

[0039] Titanium (Ti) may play a role in increasing steel sheet strength and particle size refinement. When the content of the Ti is less than 0.01%, it may be difficult to sufficiently secure the effects described above. In addition, when the content of Ti is more than 0.04%, manufacturing costs may be excessively increased, or ductility may be greatly decreased due to excessive precipitates. That is, the content of Ti may be 0.01 to 0.04%, more specifically 0.012 to 0.038%, and still more specifically 0.015 to 0.035%.

[0040] The cold-rolled steel sheet according to an example embodiment in the present disclosure may include iron (Fe) as a remaining component, while including the above components. In addition, since in a common manufacturing process, unintended impurities may be inevitably incorporated from raw materials or the surrounding environment, they may not be excluded. For example, elements which may be included in steel may be further included at a total of 1.0% or less. Since these impurities are known to any person skilled in the common manufacturing process, the entire description thereof is not particularly mentioned in the present specification.

[0041] As an example, the cold-rolled steel sheet may optionally further include one or more selected from: 0.1% or less of Cr, 0.1% or less of Mo, and 0.1% or less of niobium (Nb). Hereinafter, the reason for adding each element and the reason for limiting the content thereof will be described.

5 Chromium (Cr): 0.1% or less (including 0%)

[0042] Chromium (Cr) may increase hardenability of martensite and suppress ferrite transformation to allow martensite having appropriate strength to be finally produced. When the content of Mn is adjusted to a certain range, an effect of the content of Cr on hardenability is decreased, and thus, martensite strength may be secured without adding Cr, or a small amount of Cr may be added. When the content of Cr is more than 0.1%, a coarse Cr-based carbide is formed, and thus, cracks may be caused due to local deformation and stress occurrence in a boundary of a carbide and microstructure in the steel during part forming. That is, the content of Cr may be 0.1% or less, specifically 0.10% or less, more specifically 0.08% or less, and still more specifically 0.05% or less. Since sometimes Cr may not be added, the lower limit of the Cr content may be 0%. Additionally/alternatively, when Cr is added, the lower limit of the Cr content may be 0.001%, specifically 0.003%, and more specifically 0.005%.

Molybdenum (Mo): 0.1% or less (including 0%)

[0043] Molybdenum (Mo) is an element which increases martensite hardenability and is effective for suppressing ferrite production in a cooling zone during an annealing heat. When the content of Mo is more than 0.1%, a problem of rising costs due to the excessive amount of alloy added may arise. That is, the content of Mo may be 0.1% or less, specifically 0.10% or less, more specifically 0.08% or less, and still more specifically 0.05% or less. Since sometimes Mo may not be added, the lower limit of the Mo content may be 0%. Additionally/alternatively, when Mo is added, as a non-limiting example, the lower limit of the Mo content may be 0.01% or 0.05%.

Niobium (Nb): 0.1% or less (including 0%)

[0044] Niobium (Nb) may be segregated in an austenite grain boundary and suppress coarsening of austenite grains during an annealing heat treatment. When the content of Nb is more than 0.1%, manufacturing costs are excessively increased, or coarse precipitates are formed in a continuous casting process to cause deterioration of toughness. That is, the content of Nb may be 0.1% or less, more specifically 0.08% or less, and still more specifically 0.06% or less. Since sometimes Nb may not be added, the lower limit of the Nb content may be 0%.

[0045] As an example, the cold-rolled steel sheet may include, by area: 10 to 30% of retained austenite and 10 to 90% of the sum of bainite and martensite, as a microstructure.

[0046] When the area fraction of the retained austenite is less than 10%, a cold-rolled steel sheet having a base matrix formed of martensite may be manufactured to cause a problem of an insufficient elongation. In addition, when the area fraction of the retained austenite is more than 30%, carbon stability in retained austenite is lowered to cause martensite transformation due to deformation-induced transformation during working, thereby deteriorating formability. That is, the area fraction of retained austenite may be 10 to 30%, more specifically 12 to 28%, and still more specifically 14 to 26%.

[0047] In an example embodiment in the present disclosure, since in a composite structure steel, it is difficult to distinguish bainite and martensite by SEM observation in the microstructure, the sum of the area fractions of bainite and martensite may be controlled.

[0048] As an example, the microstructure may include both bainite and martensite, and in this case, the sum of area fractions of bainite and martensite may be 10 to 90% based on the total fraction of the microstructure. However, it is not limited thereto, and as a non-limiting example, the microstructure may include one of bainite and martensite, and in this case, the area fraction of bainite or martensite may be 10 to 90% based on the total fraction of the microstructure.

[0049] When the sum of the area fractions of bainite and martensite is less than 10%, it is difficult to sufficiently secure retained austenite, or carbon stability in retained austenite may be lowered. In addition, when the sum of the area fractions of bainite and martensite is more than 90%, it may be difficult to secure sufficient strength and/or elongation. That is, the sum of the area fractions of bainite and martensite may be 10 to 90%, more specifically 15 to 89%, and still more specifically 20 to 88%.

[0050] As an example, when the microstructure includes bainite and martensite, the area fraction of bainite may be 30 to 60%, the area fraction of martensite may be 10 to 60%, based on the total fraction of the microstructure. For example, the area fractions of bainite and martensite may be calculated by reverse estimation based on the physical properties of a final product. In addition, for example, each area fraction of bainite and martensite may also be separately calculated based on a method such as electron backscatter diffraction (EBSD), as described later.

[0051] When the area fraction of bainite is less than 30%, carbon distribution into austenite is small, and thus, a

problem of being unable to secure sufficient retained austenite may arise. In addition, when the area fraction of bainite is more than 60%, a problem of being unable to secure sufficient strength may arise. That is, the area fraction of bainite may be 30 to 60%, more specifically 35 to 55%, and still more specifically 40 to 50%.

[0052] When the area fraction of martensite is less than 10%, carbon stability in retained austenite is lowered to cause martensite transformation due to deformation-induced transformation during working, thereby deteriorating formability. In addition, when the area fraction of martensite is more than 60%, a cold-rolled steel sheet having a base matrix formed of martensite may be manufactured to cause a problem of an insufficient elongation. That is, the area fraction of martensite may be 10 to 60%, more specifically 17 to 53%, and still more specifically 24 to 46%.

[0053] As an example, the value of the following Relationship 1 of the cold-rolled steel sheet may be 0.25 to 1.5:

[Relationship 1]

$$(Mn_high - Mn_low) / Mn_base$$

wherein Mn_high is an average concentration (average content) of Mn in a region in which a content of Mn in the microstructure is at least 1% higher than an average content of Mn at a t/4 point in the thickness direction of the cold-rolled steel sheet, Mn_low is an average concentration (average content) of Mn in a region in which a content of Mn in the microstructure is at least 1% lower than the average content of Mn at the t/4 point in the thickness direction of the cold-rolled steel sheet, and Mn_base is the average content of Mn at the t/4 point in the thickness of the cold-rolled steel sheet. Herein, t may refer to the thickness of a steel sheet.

[0054] As an example, the measurement methods of Mn_high and Mn_low are not separately defined. For example, as a non-limiting example, mechanical polishing is performed from the surface of the steel sheet to a 1/4t point, based on the total thickness t of a steel sheet, and then the content of Mn may be quantitatively measured using an EPMA surface analysis at an area magnification of 30 μm×30 μm. In this case, each of a region having a locally high Mn content (for example, a region in which the content of Mn is at least 1 wt% higher than the average content of Mn of the cold-rolled steel sheet) and a region having a locally low Mn content (for example, a region in which the content of Mn is at least 1 wt% lower than the average content of Mn of the cold-rolled steel sheet) is subjected to EPMA surface analysis, thereby measuring the average content of Mn in each region.

[0055] As an example, the measurement method of Mn_base is not separately defined. For example, as a non-limiting example, during manufacture of the cold-rolled steel sheet, the content of Mn added to a slab may be interpreted as the value of Mn_base.

[0056] When the value of Relationship 1 is less than 0.25, it is difficult to generate expression of an additional strength effect resulting from a difference in the content of Mn, it is difficult to secure retained austenite, and thus, it may be difficult to secure a sufficient elongation. In addition, when the value of Relationship 1 is more than 1.5, the contents of C and Mn increase correspondingly thereto, and thus, workability is deteriorated due to the formation of Mn band and carbide in the cold-rolled steel sheet. That is, the value of Relationship 1 may be 0.25 to 1.5, specifically 0.25 to 1.50, more specifically 0.27 to 1.45, and still more specifically 0.29 to 1.40.

[0057] The cold-rolled steel sheet according to an example embodiment in the present disclosure forms martensite as a hard phase and a bainite phase as a soft phase depending on the concentration of Mn by distributing the Mn concentration in the microstructure and may induce additional reinforcement on a hard phase from deformation distribution resulting therefrom. For example, the Mn concentration distribution in the microstructure may be appropriately adjusted by controlling an annealing process. Through the Mn concentration gradient as such, bainite transformation is promoted to secure austenite stability, thereby securing retained austenite at room temperature to provide an ultra-high strength steel having an excellent elongation.

[0058] As an example, the cold-rolled steel sheet may have a tensile strength of 1500 MPa or more. Additionally/alternatively, the cold-rolled steel sheet may have an elongation of 10% or more. The tensile strength and/or elongation of the cold-rolled steel sheet meet(s) the above range, whereby the cold-rolled steel sheet may be appropriately used in cold stamping.

[0059] As an example, though a yield strength of the cold-rolled steel sheet does not need to be separately defined, as a non-limiting example, the yield strength of the cold-rolled steel sheet may be 1000 MPa or more.

[0060] Hereinafter, a manufacturing method of a cold-rolled steel sheet according to an example embodiment in the present disclosure will be described in detail. However, it does not mean that the manufacturing method of a cold-rolled steel sheet according to an example embodiment in the present disclosure should be necessarily the following manufacturing method.

[Reheating slab]

[0061] A slab having the composition described above may be reheated. Before performing hot rolling, the slab may be reheated to be homogenized. Herein, the composition of the slab is the same as the composition of the cold-rolled steel sheet described above, and the reason for adding each component and the reason for defining the content in the slab may be as described for the cold-rolled steel sheet described above.

[0062] As an example, the reheating may be performed at 1,100 to 1,300°C. When a reheating temperature is lower than 1,100°C, a load may be rapidly increased during subsequent hot rolling. In addition, the reheating temperature is higher than 1,300°C, an amount of scale on the surface may be increased to cause loss of materials. That is, the reheating temperature may be 1100 to 1300°C, more specifically 1120 to 1280°C, and still more specifically 1140 to 1260°C.

[Obtaining hot-rolled steel sheet]

[0063] The slab reheated in the operation described above may be hot rolled to obtain a hot-rolled steel sheet. For example, the temperature of the hot rolling may be 800 to 1,000°C. When the temperature of the hot rolling is lower than 800°C, a rolling load may be excessively increased due to introduction of unrecrystallized ferrite. In addition, when the temperature of the hot rolling is higher than 1,000°C, a possibility of increasing surface defects by scale and a rolling roll wear degree may be increased. That is, the temperature of the hot rolling may be 800 to 1,000°C, more specifically 810 to 990°C, and still more specifically 820 to 980°C.

[Winding]

[0064] The hot-rolled steel sheet obtained in the operation described above may be wound. For example, a winding temperature may be 400 to 700°C. When the winding temperature is lower than 400°C, the strength of the hot-rolled steel sheet is excessively increased to increase the rolling load in the cold rolling process, and also, for controlling this, control variables in the cold rolling process are increased to lower productivity. In addition, when the winding temperature is higher than 700°C, an excessive oxide film is formed on the surface of the steel sheet to cause defects (for example, surface defects). That is, the winding temperature may be 400 to 700°C, more specifically 410 to 690°C, and still more specifically 420 to 680°C.

[Obtaining cold-rolled steel sheet]

[0065] The hot-rolled steel sheet wound in the operation described above may be cold rolled to obtain a cold-rolled steel sheet. For example, the cold rolling may be performed at a reduction rate of 20 to 75%. When the reduction rate is less than 20%, it is difficult to secure the target thickness, and also, production of austenite in an annealing process and the final physical properties of a steel sheet may be affected due to the remaining grains produced in the hot rolling process. In addition, when the reduction rate is more than 75%, the load of the cold rolling mill is increased to deteriorate workability. That is, the reduction rate during the cold rolling may be 20 to 75%, more specifically 25 to 70%, and still more specifically 30 to 65%.

[0066] As an example, before performing the cold rolling, the wound hot-rolled steel sheet may be pickled. Through the pickling treatment, an oxide layer formed on the surface of the steel sheet may be removed. The pickling method is not particularly limited, and a method commonly used in the art (for example, adding a steel sheet into a hydrochloric acid bath) may be applied.

[0067] FIG. 1 is a schematic diagram showing a manufacturing method of a cold-rolled steel sheet according to an example embodiment of the present disclosure. Referring to FIG. 1, the manufacturing method of a cold-rolled steel sheet according to an example embodiment in the present disclosure may include a two-stage annealing process including primary annealing, secondary annealing, primary cooling, secondary cooling, and maintaining constant temperature. Through the two-stage annealing process, a high-stretched cold-rolled steel sheet having mechanical properties of an elongation of 10% or more, while securing a tensile strength of a 1.5 GPa grade or higher.

[0068] Hereinafter, each process will be described in detail.

[Primary annealing]

[0069] The cold-rolled steel sheet obtained in the operation described above may be primarily annealed in a primary annealing temperature. A Mn concentration difference between ferrite and austenite produced in a two-phase region is generated by the primary annealing operation, and ferrite having a low Mn concentration and austenite having a high Mn concentration may be formed.

[0070] As an example, the Mn concentration difference may be greatly increased by appropriately adjusting a primary annealing temperature and/or a maintenance time at the primary annealing temperature. For example, the primary annealing temperature may be 700 to 800°C. Herein, though the measurement method of the primary annealing temperature is not separately defined, the surface temperature of the steel sheet may be measured as the primary annealing temperature. When the primary annealing temperature is lower than 700°C, an austenite phase is not produced, C and Mn distribution does not appropriately occur, and thus, the Mn concentration difference does not occur even after the secondary annealing, which may make it difficult to secure target physical properties. In addition, when the primary annealing temperature is higher than 800°C, an austenite phase is excessively produced, and an effect of distributing C and Mn into austenite may be exhibited, but the C and Mn concentration difference is decreased, and thus, it may be difficult to secure a retained austenite fraction and a sufficient elongation. That is, the primary annealing temperature may be 700 to 800°C, more specifically 705 to 795°C, and still more specifically 710 to 790°C.

[0071] As an example, the primary annealing may be performed by maintaining the cold-rolled steel sheet at the primary annealing temperature for 10 minutes to 24 hours. Specifically, heating is performed so that the highest temperature is the primary annealing temperature (that is, 700 to 800°C) based on the surface temperature of the steel sheet, and the steel sheet may be maintained at the primary annealing temperature for 10 minutes to 24 hours from the point when the highest temperature has been reached. Since the maintenance time at the primary annealing temperature is adjusted to the range, the Mn concentration difference may be further greatly increased.

[0072] When the maintenance time at the primary annealing temperature is less than 10 minutes, the C and Mn distribution effect in the two-phase region temperature range is insignificant, the C and Mn concentration becomes uniform, the Mn concentration difference becomes smaller, and thus, it may be difficult to secure the retained austenite fraction and a sufficient elongation. In addition, when the maintenance time at the primary annealing temperature is more than 24 hours, strength is lowered due to grain coarsening, or heterogeneity of C and Mn concentrations in ferrite and/or austenite becomes worse. That is, the maintenance time at the primary annealing temperature may be 10 minutes to 24 hours, more specifically 12 minutes to 23 hours, and still more specifically 14 minutes to 22 hours.

[Secondary annealing]

[0073] The cold-rolled steel sheet which is primarily annealed in the operation described above may be secondarily annealed at a secondary annealing temperature. Through the secondary annealing operation, the targeted composition and area fraction of the microstructure may be appropriately secured, while appropriately maintaining the Mn distribution obtained from the primary annealing.

[0074] The secondary annealing temperature may be equal to or higher than the austenite single phase region. Herein, though the measurement method of the secondary annealing temperature is not separately defined, the surface temperature of the steel sheet may be measured as the secondary annealing temperature. By adjusting the secondary annealing temperature to the range described above, 10% or more bainite and martensite may be secured from austenite in which Mn has been distributed. When the secondary annealing temperature is lower than the austenite single phase region, it may be difficult to appropriately secure bainite and/or martensite. In addition, though the upper limit of the secondary annealing is not separately defined, as a non-limiting example, the upper limit of the secondary annealing temperature may be 950°C.

[0075] As an example, the steel sheet may be heated to the secondary annealing temperature at an average heating rate of 2°C/s or more. By adjusting the average heating rate to the above range, Mn distribution obtained from the primary annealing operation may be maintained. When the average heating rate is less than 2°C/s, Mn is redistributed, and thus, a Mn concentration difference is greatly decreased, and the Mn concentration becomes uniform overall. That is, the average heating rate may be 2°C/s or more, more specifically 3°C/s or more, and still more specifically 4°C/s or more. In addition, though the upper limit of the average heating rate is not separately defined, as a non-limiting example, the upper limit of the average heating rate may be 500°C/s.

[0076] As an example, the secondary annealing may be performed by maintaining the primarily annealed cold-rolled steel sheet at the secondary annealing temperature for more than 0 seconds and 10 seconds or less. Specifically, heating is performed so that the highest temperature is the secondary annealing temperature (that is, a temperature at or above the austenite single phase region), based on the surface temperature of the steel sheet, and the steel sheet may be maintained at the secondary annealing for more than 0 seconds and 10 seconds or less from the point when the highest temperature has been reached.

[0077] When the maintenance time at the secondary annealing temperature is more than 10 seconds, Mn is redistributed, and thus, the Mn concentration difference is greatly decreased, the Mn concentration becomes uniform overall, and it may be difficult to secure the fraction of retained austenite. That is, the maintenance time at the secondary annealing temperature may be more than 0 seconds and 10 seconds or less, more specifically 1 to 9 seconds, and still more specifically 2 to 8 seconds.

[Cooling]

[0078] The cold-rolled steel sheet which is secondarily annealed in the operation described above may be cooled to a cooling end temperature in the predetermined range. Through the cooling operation, the cold-rolled steel sheet having the sum of area fractions of martensite and bainite of 40% or more may be secured. Additionally/alternatively, through the cooling operation, a cold-rolled steel sheet having the area fraction of retained austenite of 10% or more may be secured.

[0079] The cooling end temperature may be a bainite transformation zone temperature. Specifically, the cooling end temperature may be 280 to 480°C. When the cooling end temperature is lower than 280°C or higher than 480°C, the bainite phase is not sufficiently secured, retained austenite produced during final cooling may not be secured, and thus, a problem may arise in securing an elongation. That is, the cooling end temperature may be 280 to 480°C, more specifically 290 to 470°C, and still more specifically 300 to 460°C.

[0080] As an example, the cooling may be performed by cooling to the cooling end temperature at an average cooling rate of 10°C/s or more. When the average cooling rate is less than 10°C/s, a pearlite or bainite phase may be excessively introduced during cooling to cause a decrease in tensile strength and/or elongation. That is, the average cooling rate may be 10°C/s or more, more specifically 12°C/s or more, and still more specifically 14°C/s or more. In addition, though the upper limit of the average cooling rate is not separately defined, as a non-limiting example, the upper limit of the average cooling rate may be 50°C/s.

[Maintaining constant temperature]

[0081] The cold-rolled steel sheet which is cooled in the operation described above may be maintained at the cooling end temperature (for example, 280 to 480°C which is the bainite transformation section temperature range). When the constant temperature maintenance temperature is lower than 280°C or higher than 480°C, the bainite phase is not sufficiently secured, retained austenite produced during final cooling may not be secured, and thus, a problem may arise in securing an elongation.

[0082] The cooled cold-rolled steel sheet may be maintained at the cooling end temperature for 5 minutes to 5 hours. When the constant temperature maintenance time is less than 5 minutes, there is not enough time required for bainite transformation, and thus, it may be difficult to secure the fraction of retained austenite. In addition, when the constant temperature maintenance time is more than 5 hours, the fraction of retained austenite may not be secured due to the redistribution of Mn. That is, the constant temperature maintenance time may be 5 minutes to 5 hours, more specifically 6 minutes to 4.5 hours, and still more specifically 7 minutes to 4 hours.

[0083] According to the manufacturing method according to an example embodiment in the present disclosure, a cold-rolled steel sheet having mechanical properties such as a tensile strength of a 1.5 GPa grade or higher and/or an elongation of 10% or more may be secured. More specifically, the tensile strength and/or elongation at a target level may be secured by precisely controlling the primary annealing temperature, the primary annealing time, the secondary annealing temperature, the secondary annealing time, and the cooling end temperature, in the two-stage annealing process. Mode for Invention

[0084] 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 in detail by illustration and are not intended to limit the right scope 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)

[0085] A slab having the alloy composition of the following Table 1 (residual components of the alloy composition: Fe and unavoidable impurities, and in Table 1, N is expressed in ppm units and the remaining components are expressed in wt% units) was dissolved in vacuum with an ingot, maintained at 1200°C for 1 hour, and finish rolled at 900°C to obtain a hot-rolled steel sheet. Thereafter, the hot-rolled steel sheet was charged into a furnace preheated to 600°C, maintained for 1 hour, and wound through furnace cooling. The wound hot-rolled steel sheet was pickled and cold rolled at a reduction rate of 50% to obtain a cold-rolled steel sheet.

[0086] The cold-rolled steel sheet obtained as described above was heated to various two-phase region temperature ranges in the conditions described in the following Table 2 to proceed with primary annealing and then was secondarily annealed at the temperature at or above the austenite single phase region. Subsequently, the secondarily annealed cold-rolled steel sheet was cooled to the cooling temperature (average cooling rate: 10°C/s) in the conditions described in the following Table 2 and then was maintained at the constant cooling temperature.

EP 4 826 062 A1

[Table 1]

Steel type	Classification	Alloy composition											
		C	Si	Mn	P	S	Al	Cr	Ti	Nb	B	N	Mo
A	Inventive steel	0.28	1.5	3.8	0.01	0.002	0.025	0	0.02	0	0.002	40	0
B	Inventive steel	0.25	1.4	4	0.01	0.002	0.025	0.05	0.02	0	0.002	40	0
C	Inventive steel	0.3	1.5	3.5	0.01	0.002	0.025	0.1	0.025	0.04	0.002	40	0.05
D	Comparative steel	0.15	1.4	3	0.01	0.002	0.025	0.1	0.025	0.04	0.002	40	0.05
E	Comparative steel	0.3	1.5	2	0.01	0.002	0.025	0.1	0.025	0.04	0.002	40	0.05
F	Comparative steel	0.25	0.5	3.5	0.01	0.002	0.025	0	0.02	0	0.002	40	0

[Table 2]

Classification	Steel type	Primary annealing		Secondary annealing		Cooling	Maintaining constant temperature
		Temperature (°C)	Maintenance time (min)	Temperature (°C)	Maintenance time (min)	Cooling end temperature (°C)	Maintenance time (min)
Comparative Example 1	A	750	5	900	5	350	120
Inventive Example 1	A	750	10	900	5	350	120
Inventive Example 2	A	750	30	900	5	300	120
Comparative Example 2	A	820	30	900	5	350	120
Inventive Example 3	B	730	60	900	5	330	60
Comparative Example 3	B	750	30	900	60	300	3
Comparative Example 4	B	660	30	900	5	300	120
Inventive Example 4	C	750	20	900	5	330	60
Comparative Example 5	D	750	30	900	5	300	120
Comparative Example 6	D	730	60	900	5	330	60
Comparative Example 7	E	750	30	900	5	300	120
Comparative Example 8	E	730	60	900	5	330	60
Comparative Example 9	E	750	20	900	5	330	60
Comparative Example 10	F	750	30	900	5	300	120

[0087] The value of Relationship 1, the fraction of the microstructure, and the mechanical properties (yield strength,

tensile strength, and elongation) of each of the manufactured cold-rolled steel sheets were measured, and the results are shown in Table 3.

[0088] The value of Relationship 1 was calculated by the formula of $[(Mn_high - Mn_low)/Mn_base]$. Specifically, mechanical polishing was performed on each cold-rolled steel sheet from the surface of the steel sheet to a $1/4t$ point, based on the total thickness t of a steel sheet, and then the content of Mn was measured using EPMA surface analysis at a magnification of 1,000 times or more. At this time, the average concentration of Mn in a region having at least 1 wt% higher than the average Mn content of the cold-rolled steel sheet was measured as Mn_high, and the average concentration of Mn in a region having at least 1 wt% lower than the average Mn content of the cold-rolled steel sheet was measured as Mn_low. In addition, Mn_base was expressed as the content of Mn contained in the slab during manufacture of each cold-rolled steel sheet.

[0089] The fraction of the microstructure was measured for each cold-rolled steel sheet, using XRD analysis equipment and a magnetic induction method (Metis). Specifically, the fraction of retained austenite including micro-austenite in the steel sheet was measured, and for the other fractions, the fractions of bainite and martensite were calculated through an optical microscope, a scanning electron microscope, and EBSD analysis equipment. At this time, since bainite and martensite has a BCC structure, it is difficult to distinguish them easily. Considering this, since martensite has a higher potential density than bainite and has a characteristic of not having a specific crystal orientation, bainite and martensite were distinguished using an IQ distribution and a KAM index. First, since a phase having a potential density or lattice distortion has a lower image quality (IQ) value, individual peaks having an IQ distribution were distinguished using a Gaussian function. In addition, since the criteria for the overlapping portion and the threshold value of the IQ distribution are different from the positions of the specimen or EBSD measurement conditions, a KAM index was used to complement this. Specifically, since martensite is subjected to compression stress due to volume expansion by phase transformation and a disordered crystal orientation, it has a high KAM index. As such, bainite and martensite were distinguished by combining the IQ distribution and the KAM index. In the present experiment, the structure having a low IQ threshold or a KAM threshold of more than 2.5 was distinguished as martensite. In addition, the structure having a high IQ threshold and a KAM threshold of 2.5 or less was distinguished as bainite.

[0090] In order to measure the mechanical properties, each cold-rolled steel sheet was worked perpendicular to the rolling direction according to the JIS standard specifications, and then a tensile tester and an elongation meter were attached thereto to measure the yield strength, the tensile strength, and the elongation.

[Table 3]

Classification	Relationship 1	Microstructure (% by area)			Mechanical properties		
		M	B	γ	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
Comparative Example 1	0.21	65	30	5	1146	1749	6.7
Inventive Example 1	0.59	30	48	22	1054	1694	13.5
Inventive Example 2	0.68	20	54	26	1021	1643	16.2
Comparative Example 2	0.14	68	28	4	1162	1764	7.9
Inventive Example 3	0.75	43	38	19	1086	1780	12.3
Comparative Example 3	0.12	63	35	2	1243	1905	5.8
Comparative Example 4	0.09	69	29	2	1197	1886	4.9
Inventive Example 4	0.86	28	51	21	1107	1805	12.8
Comparative Example 5	0.72	27	50	23	968	1452	14.6
Comparative Example 6	0.83	43	39	18	979	1467	13.1
Comparative Example 7	1.25	42	50	8	1178	1754	8.2
Comparative Example 8	1.21	39	55	6	1184	1798	7.3
Comparative Example 9	1.18	44	52	4	1179	1788	6.9
Comparative Example 10	0.69	50	45	5	1082	1657	7.5
- M: Martensite							

(continued)

Classification	Relationship 1	Microstructure (% by area)			Mechanical properties		
		M	B	γ	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
- B: Bainite - γ: Retained austenite							

[0091] Inventive Examples 1 to 4 which satisfied the alloy composition and manufacturing conditions suggested in the present disclosure had the values of Relationship 1 derived to an appropriate level, and thus, were confirmed to secure the tensile strength of 1500 MPa or more, the yield strength of 1000 MPa or more, and the elongation of 10% or more.

[0092] A photograph in which the microstructure of the cold-rolled steel sheet of Inventive Example 3 was observed is shown in FIG. 2, as a representative of the inventive examples. Specifically, (a) of FIG. 2 is a photograph in which the microstructure of Inventive Example 3 was observed by a scanning electron microscope (FE-SEM). In addition, (b) of FIG. 2 is a photograph in which the microstructure of Inventive Example 3 was observed by electron backscatter diffraction (EBSD) and shows an enlarged phase distribution map of an area in which retained austenite was distributed, for Inventive Example 3.

[0093] Referring to FIG. 2, it was found that a large amount of retained austenite was secured from the non-uniform Mn content gradient rather than from the controlling of the microstructure having a uniform chemical composition. Accordingly, it was confirmed that ultra-high strength of a 1.5 GPa grade or higher and an excellent elongation were secured.

[0094] More specifically, referring to (a) of FIG. 2, an area appearing relatively dark shows bainite, and an area appearing relatively light shows martensite. That is, it was found that martensite as a hard phase and bainite as a soft phase were appropriately formed from the Mn gradient.

[0095] In addition, referring to (b) of FIG. 2, an area appearing in a bright color (white) shows retained austenite. That is, it was found that a large amount of retained austenite was secured from the non-uniform Mn content gradient.

[0096] Meanwhile, since in Comparative Example 1 having an excessively short maintenance time of the primary annealing, the Mn distribution did not sufficiently occur, the value of Relationship 1 (that is, Mn concentration difference) was calculated to be very small. Thus, it was found that it was difficult to secure the fraction of retained austenite, and the elongation was less than 10%.

[0097] In addition, Comparative Example 2 having an excessively high primary annealing temperature had an insignificant Mn distribution effect, and the value of Relationship 1 (that is, Mn concentration difference) was calculated to be very small. Accordingly, it was found that it was difficult to secure the fraction of retained austenite, and the elongation was less than 10%.

[0098] In addition, in Comparative Example 3 having an excessively long maintenance time of the secondary annealing and an excessively short constant temperature maintenance time, Mn was redistributed, and thus, the Mn concentration difference was greatly decreased, and the Mn concentration became uniform overall. Accordingly, in Comparative Example 3, it was found that it was difficult to secure the fraction of retained austenite, and the elongation was less than 10%.

[0099] In addition, in Comparative Example 4 having an excessively low primary annealing temperature, cementite produced in the ferrite phase was not completely dissolved and remained even after the secondary annealing. Accordingly, in Comparative Example 4, it was found that the area fraction of the microstructure was not able to be secured to an appropriate level, and the elongation was less than 10%.

[0100] In addition, in Comparative Examples 5 to 10 which did not satisfy the alloy composition suggested in the present disclosure, it was confirmed that the yield strength, the tensile strength, and/or the elongation at target levels in the present disclosure were not able to be secured.

[0101] The above embodiment is one example, and the present disclosure is not limited thereto. Any of those having substantially the same configuration and the same working effect as the technical idea described in the claims of the present disclosure is included in the technical scope of the present disclosure.

Claims

1. A cold-rolled steel sheet comprising, by weight: 0.2 to 0.4% of C, 1.0 to 2.0% of Si, 2.5 to 5.0% of Mn, 0.1% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.01 to 0.1% of Al, 0.01% or less (excluding 0%) of N,

0.005% or less (excluding 0%) of B, 0.01 to 0.04% of Ti, a remainder of Fe, and unavoidable impurities, and

wherein the cold-rolled steel sheet includes, by area: 10 to 30% of retained austenite and 10 to 90% of the sum of bainite and martensite, as a microstructure, and
a value of the following Relationship 1 is 0.25 to 1.5:

[Relationship 1]

$$(Mn_high - Mn_low) / Mn_base$$

wherein Mn_high is an average concentration of Mn in a region in which a content of Mn in the microstructure is at least 1% higher than an average content of Mn at a t/4 point in the thickness direction of the cold-rolled steel sheet, Mn_low is an average concentration of Mn in a region in which a content of Mn in the microstructure is at least 1% lower than the average content of Mn at the t/4 point in the thickness direction of the cold-rolled steel sheet, and Mn_base is the average content of Mn at the t/4 point in the thickness of the cold-rolled steel sheet.

2. The cold-rolled steel sheet of claim 1, wherein an area fraction of the bainite is 30 to 60% based on the total fraction of the microstructure.
3. The cold-rolled steel sheet of claim 1, wherein an area fraction of the martensite is 10 to 60% based on the total fraction of the microstructure.
4. The cold-rolled steel sheet of claim 1, further comprising, by weight: one or more selected from 0.1% or less of Cr, 0.1% or less of Mo, and 0.1% or less of Nb.
5. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a tensile strength of 1500 MPa or more and an elongation of 10% or more.
6. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a yield strength of 1000 MPa or more.
7. A manufacturing method of a cold-rolled steel sheet, the method comprising:
reheating a slab including, by weight: 0.2 to 0.4% of C, 1.0 to 2.0% of Si, 2.5 to 5.0% of Mn, 0.1% or less (excluding 0%) of P, 0.03% or less (excluding 0%) of S, 0.01 to 0.1% of Al, 0.01% or less (excluding 0%) of N, 0.005% or less (excluding 0%) of B, 0.01 to 0.04% of Ti, a remainder of Fe, and unavoidable impurities;
hot rolling the reheated slab to obtain a hot-rolled steel sheet;
winding the hot-rolled steel sheet;
cold rolling the wound hot-rolled steel sheet to obtain a cold-rolled steel sheet;
performing primary annealing of maintaining the cold-rolled steel sheet at a primary annealing temperature of 700 to 800°C for 10 minutes to 24 hours;
performing a secondary annealing of maintaining the primarily annealed cold-rolled steel sheet at a secondary annealing temperature at or above an austenite single phase region for a period of time of more than 0 seconds and 10 seconds or less;
cooling the secondarily annealed cold-rolled steel sheet to a cooling end temperature of 280 to 480°C; and
maintaining the cooled cold-rolled steel sheet at the cooling end temperature for 5 minutes to 5 hours.
8. The manufacturing method of a cold-rolled steel sheet of claim 7, wherein the secondary annealing is performed by heating to the secondary annealing temperature at an average heating rate of 2°C/s or more.
9. The manufacturing method of a cold-rolled steel sheet of claim 7, wherein the cooling is performed by cooling to the cooling end temperature at an average cooling rate of 10°C/s or more.
10. The manufacturing method of a cold-rolled steel sheet of claim 7, wherein the reheating is performed at 1,100 to 1,300°C, and the obtaining of a hot-rolled steel sheet is performed by hot rolling the reheated slab at 800 to 1,000°C.

11. The manufacturing method of a cold-rolled steel sheet of claim 7, wherein the winding is performed at 400 to 700°C, and the obtaining of a cold-rolled steel sheet is performed by cold rolling the wound hot-rolled steel sheet at a reduction rate of 20 to 75%.

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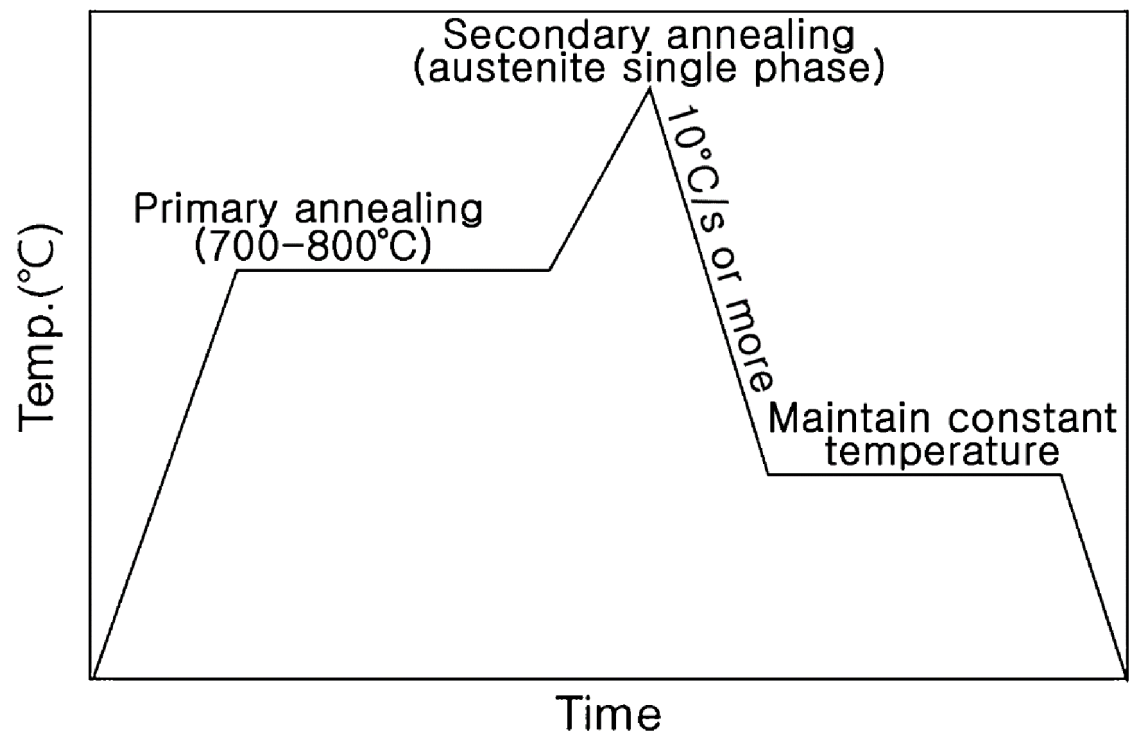
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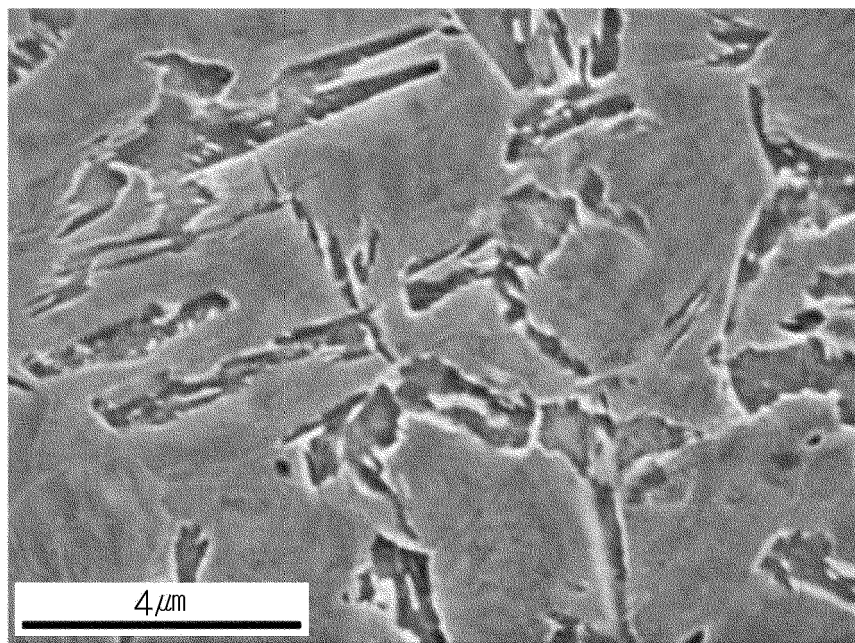
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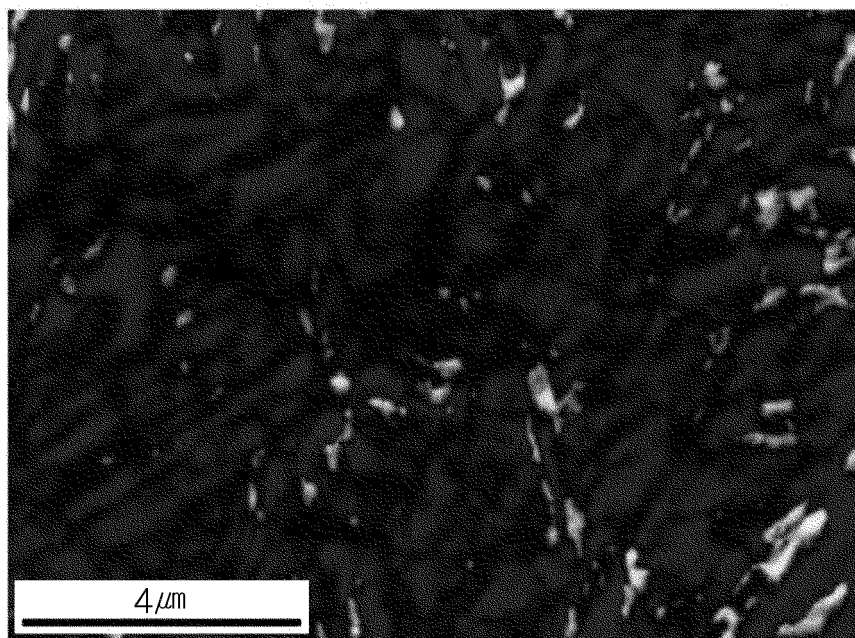
[Fig.1]



[Fig.2]



(a)



(b)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020344

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; **C22C 38/02**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/00**(2006.01)i; **C22C 38/14**(2006.01)i;
C22C 38/34(2006.01)i; **C22C 38/38**(2006.01)i; **C21D 8/02**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/04(2006.01); B21C 47/02(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01);
C22C 38/06(2006.01); C22C 38/14(2006.01)

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

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

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

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

eKOMPASS (KIPO internal) & keywords: 인장강도(tensile strength), 연신율(elongation), 망간(Mn), 소둔
(annealing), 베이나이트(bainite), 마르텐사이트(martensite)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-1594670 B1 (POSCO) 17 February 2016 (2016-02-17) See claims 1-9.	1-11
A	KR 10-2023-0081744 A (POSCO) 08 June 2023 (2023-06-08) See claims 1-6.	1-11
A	JP 2013-221198 A (NIPPON STEEL & SUMITOMO METAL CORP.) 28 October 2013 (2013-10-28) See paragraphs [0062]-[0073] and claims 1 and 6.	1-11
A	KR 10-1985123 B1 (JFE STEEL CORPORATION) 31 May 2019 (2019-05-31) See paragraphs [0113]-[0125] and claims 1 and 4.	1-11
A	KR 10-2274284 B1 (JFE STEEL CORPORATION) 06 July 2021 (2021-07-06) See paragraphs [0169]-[0210] and claims 1 and 6.	1-11

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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“O” document referring to an oral disclosure, use, exhibition or other means

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

18 March 2025

Date of mailing of the international search report

18 March 2025

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020344

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
5 10 15	KR 10-1594670 B1 17 February 2016	CN 107075649 A	18 August 2017
		CN 107075649 B	30 November 2018
		EP 3144406 A1	22 March 2017
		EP 3144406 B1	31 July 2019
		JP 2017-519900 A	20 July 2017
		JP 6383808 B2	29 August 2018
		KR 10-2015-0130612 A	24 November 2015
		US 10519526 B2	31 December 2019
		US 2017-0051378 A1	23 February 2017
		WO 2015-174605 A1	19 November 2015
20	KR 10-2023-0081744 A 08 June 2023	CN 118613601 A	06 September 2024
		EP 4442851 A1	09 October 2024
		JP 2024-543182 A	19 November 2024
		KR 10-2024-0113726 A	23 July 2024
		KR 10-2722677 B1	30 October 2024
		US 2025-0011889 A1	09 January 2025
		WO 2023-096453 A1	01 June 2023
25	JP 2013-221198 A	JP 5825185 B2	02 December 2015
	KR 10-1985123 B1	CN 107250409 A	13 October 2017
30	31 May 2019	CN 107250409 B	05 July 2019
		EP 3228722 A1	11 October 2017
		EP 3228722 B1	20 March 2019
		JP 6237900 B2	29 November 2017
		JP WO2016-132680 A1	27 April 2017
		KR 10-2017-0102989 A	12 September 2017
		MX 2017010539 A	14 December 2017
		US 10626485 B2	21 April 2020
		US 2018-0057916 A1	01 March 2018
		WO 2016-132680 A1	25 August 2016
35	KR 10-2274284 B1 06 July 2021	CN 110475892 A	19 November 2019
		CN 110475892 B	14 January 2022
		EP 3591087 A1	08 January 2020
		EP 3591087 B1	09 June 2021
		JP 2018-178247 A	15 November 2018
		JP 6409991 B1	24 October 2018
		KR 10-2019-0125407 A	06 November 2019
		US 11365459 B2	21 June 2022
		US 2020-0040421 A1	06 February 2020
		WO 2018-186335 A1	11 October 2018

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- KR 1020177022118 [0007]
- JP 2017145469 A [0007]