



(11)

EP 4 826 084 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
21.10.2026 Bulletin 2026/43

(21) Application number: **24904427.2**

(22) Date of filing: **13.12.2024**

(51) International Patent Classification (IPC):
C22C 38/38 ^(2006.01) **C22C 38/26** ^(2006.01)
C22C 38/28 ^(2006.01) **C22C 38/00** ^(2006.01)
C21D 8/02 ^(2026.01) **C21D 9/46** ^(2006.01)
C23C 2/06 ^(2006.01)

(52) Cooperative Patent Classification (CPC):
C21D 8/02; C21D 9/46; C22C 38/00; C22C 38/26;
C22C 38/28; C22C 38/38; C23C 2/06

(86) International application number:
PCT/KR2024/096921

(87) International publication number:
WO 2025/127862 (19.06.2025 Gazette 2025/25)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **15.12.2023 KR 20230183881**

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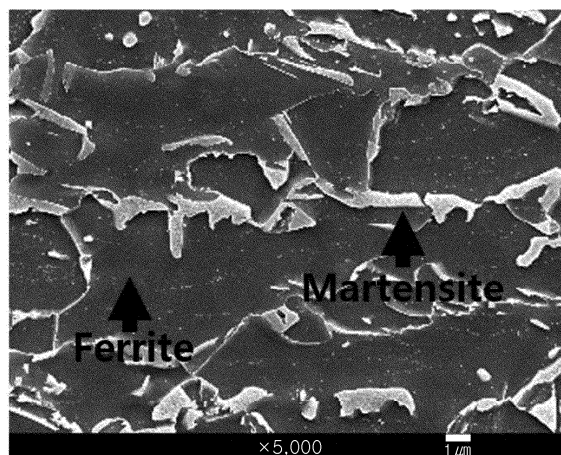
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(54) **STEEL SHEET AND MANUFACTURING METHOD THEREOF**

(57) One aspect of the present invention provides a steel sheet having excellent bendability and a manufacturing method thereof.

[Fig.1]



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Description

Technical Field

5 **[0001]** The present disclosure relates to a steel sheet and a method for manufacturing the same.

Background Art

10 **[0002]** Recently, safety regulations for automobiles have been strengthened to ensure safety during a vehicle collision, and accordingly, there have been attempts to increase the strength and/or thickness of steel sheets for automobiles. However, there is a growing demand for weight reduction of the vehicle body to address environmental issues and improve fuel efficiency.

[0003] Accordingly, increasing the strength of steel sheets is essential to simultaneously ensure collision safety and weight reduction of automobiles. Generally, solid-solution strengthening, precipitation strengthening, strengthening by grain refinement, and transformation strengthening are used as methods for strengthening steel.

15 **[0004]** Among these, high-strength steel using precipitation strengthening is a technology that secures strength by adding carbide- and nitride-forming elements such as Cu, Nb, Ti, and V to precipitate carbides and nitrides to strengthen the steel sheet, or by refining grains through the suppression of grain growth by fine precipitates.

[0005] This precipitation strengthening technology can easily obtain high strength at a low manufacturing cost, but it has a disadvantage in that a high-temperature annealing must be performed to secure ductility through sufficient recrystallization, as the recrystallization temperature increases sharply due to fine precipitates. In addition, precipitation-strengthened steel, which is strengthened by precipitating carbides and nitrides in a ferrite matrix, has a problem of increased cost due to the excessive addition of precipitation elements to obtain high-strength steel of 600 MPa or higher.

25 **[0006]** Meanwhile, as high-strength steels using transformation strengthening, various types of steels have been developed, such as Dual Phase (DP) steel, in which a hard martensite is included in a ferrite matrix; Transformation Induced Plasticity (TRIP) steel, which utilizes the transformation-induced plasticity of retained austenite; or Complexed Phase (CP) steel, which is composed of a ferrite and a hard bainite (or martensite) structure.

30 **[0007]** As a conventional technology for such high-strength steel sheets, Patent Document 1 discloses a cold-rolled steel sheet composed of a composite structure including ferrite, bainite, martensite, and retained austenite. However, Patent Document 1 has a limitation in that the excessive addition of Si causes furnace dent during continuous annealing or leads to liquid metal embrittlement during spot welding.

[0008] (Patent Document 1) Korean Patent Laid-Open Publication No. 10-2019-0076258

35 Summary of the Invention

Technical Problem

40 **[0009]** An aspect of the present disclosure is to provide a steel sheet with excellent bendability and a method for manufacturing the same.

[0010] The objects of the present disclosure are not limited to the matters mentioned above. Additional objects of the present disclosure are described throughout the specification, and a person having ordinary skill in the art to which the present disclosure pertains will have no difficulty in understanding the additional objects of the present disclosure from the contents described in the specification.

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Solution to Problem

50 **[0011]** An aspect of the present disclosure provides a steel sheet. The steel sheet may include, by weight%, 0.05% to 0.18% of carbon (C), 0.1% or less of silicon (Si), 1.0% to 2.3% of manganese (Mn), 1.0% or less of soluble aluminum (sol.Al), 0.1% to 1.0% of chromium (Cr), 0.05% or less of niobium (Nb), 0.05% or less of titanium (Ti), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), 0.01% or less of nitrogen (N), a remainder of iron (Fe), and other inevitable impurities, wherein a T value defined by Equation 1 below is 1380 or more and less than 1648, and a microstructure may include, by area%, 65% to 85% of ferrite, 10% or less of bainite, 6% to 20% of fresh martensite, and 5% or less of retained austenite.

55

[Equation 1]

$$T = 279 \times [C] + 711 \times [Mn] + 474 \times [Nb] + 177 \times [Ti] - 75 \times [Cr]$$

(In Equation 1, [C], [Mn], [Nb], [Ti], and [Cr] represent the content (wt%) of each element.)

[0012] In addition, in the aforementioned steel sheet, the steel sheet may have an RT value of 0.01 or more, as defined by Equation 2 below.

[Equation 2]

$$RT = [Si] + [Nb] + [Ti]$$

(In Equation 2, [Si], [Nb], and [Ti] represent the content (wt%) of each element.)

[0013] In addition, in one of the aforementioned steel sheets, the steel sheet may have a tensile strength of 590 MPa or more and an elongation of 20% or more.

[0014] In addition, in one of the aforementioned steel sheets, the steel sheet may satisfy Equation 3 below.

[Equation 3]

$$A/TH \geq 60 \text{ (}^\circ/\text{mm)}$$

(In Equation 3, A represents the bending angle (°) at which no cracks occur in the bent portion during a 180° bending test, and TH represents the thickness (mm) of the steel sheet.)

[0015] In addition, in one of the aforementioned steel sheets, the steel sheet may further include a galvanized layer or a galvanized layer on its surface.

[0016] Another aspect of the present disclosure provides a method for manufacturing a steel sheet. The method may include: reheating a steel slab including, by weight%, 0.05% to 0.18% of carbon (C), 0.1% or less of silicon (Si), 1.0% to 2.3% of manganese (Mn), 1.0% or less of soluble aluminum (sol.Al), 0.1% to 1.0% of chromium (Cr), 0.05% or less of niobium (Nb), 0.05% or less of titanium (Ti), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), 0.01% or less of nitrogen (N), a remainder of iron (Fe), and other inevitable impurities, wherein a T value defined by Equation 1 below is 1380 or more and less than 1648; hot-rolling the reheated steel slab to obtain a hot-rolled steel sheet; coiling the hot-rolled steel sheet; cold-rolling the coiled hot-rolled steel sheet to obtain a cold-rolled steel sheet; heating the cold-rolled steel sheet to an annealing temperature of 800°C to 850°C, cooling it to a cooling-end temperature of 450°C to 600°C, and then holding it at a constant temperature for continuous annealing; and cooling the continuously annealed steel sheet to room temperature, wherein an R value defined by Equation 4 below may be 1,543 to 1,590.

[Equation 1]

$$T = 279 \times [C] + 711 \times [Mn] + 474 \times [Nb] + 177 \times [Ti] - 75 \times [Cr]$$

(In Equation 1, [C], [Mn], [Nb], [Ti], and [Cr] represent the wt% of each element.)

$$R = 174 \times [C] + 680 \times [Mn] + 370 \times [Nb] + 177 \times [Ti] - 86 \times [Cr] + 0.33 \times [T1] - 0.05 \times [T2] \quad \text{[Equation 4]}$$

(In Equation 4, [C], [Mn], [Nb], [Ti], and [Cr] represent the content (wt%) of each element, and [T1] and [T2] represent the annealing temperature (°C) and the cooling-end temperature (°C) in the continuous annealing step, respectively.)

[0017] In addition, in the aforementioned method, in the reheating step, the steel slab may have an RT value of 0.01 or more as defined by Equation 2 below.

[Equation 2]

$$RT = [Si] + [Nb] + [Ti]$$

(In Equation 2, [Si], [Nb], and [Ti] represent the content (wt%) of each element.)

[0018] In addition, in one of the aforementioned methods, the reheating step may be performed at 1,100°C to 1,300°C, and the step of obtaining the hot-rolled steel sheet may be performed at a finish rolling temperature of 800°C to 950°C.

[0019] In addition, in one of the aforementioned methods, in the coiling step, the hot-rolled steel sheet may be coiled at 400°C to 700°C and then cooled to room temperature at an average cooling rate of 0.1°C/s or less.

[0020] In addition, in one of the aforementioned methods, the step of obtaining the cold-rolled steel sheet may be performed with a reduction ratio of 40% to 70%.

[0021] In addition, in one of the aforementioned methods, in the continuous annealing step, cooling to the cooling-end temperature may be performed at an average cooling rate of 20°C/s or less.

[0022] In addition, in one of the aforementioned methods, in the continuous annealing step, the cold-rolled steel sheet may be held at the cooling-end temperature for 50 seconds or more.

[0023] In addition, one of the aforementioned methods may further include, after the continuous annealing step, a step of galvanizing the continuously annealed steel sheet at 430°C to 490°C.

[0024] In addition, one of the aforementioned methods may further include, after the galvanizing step, a step of subjecting the galvanized steel sheet to an alloying heat treatment at 460°C to 530°C.

Advantageous Effects of Invention

[0025] According to the present disclosure, a steel sheet with excellent bendability and a method for manufacturing the same can be provided.

[0026] In addition, according to the present disclosure, the steel sheet has improved workability, can be used in complex shapes during press forming, and can be suitably utilized for structural members of automobiles.

[0027] The various and beneficial advantages and effects of the present disclosure are not limited to the above-described contents and will be more easily understood in the course of describing specific embodiments of the present disclosure.

Brief Description of the Drawings

[0028] For a more complete understanding of the drawings cited in the detailed description of the present disclosure, a brief description of each drawing is provided.

FIG. 1 is a photograph showing the microstructure of Inventive Example 13 according to an embodiment of the present disclosure, observed with an electron microscope.

FIG. 2 is a photograph showing the microstructure of Comparative Example 6 according to an embodiment of the present disclosure, observed with an electron microscope.

Best Mode for Invention

[0029] Hereinafter, preferred embodiments of the present disclosure will be described. However, the embodiments of the present disclosure may be modified into various other forms, and the terms used in this specification are for describing the present disclosure and are not intended to limit the present disclosure. In addition, the singular forms used in this specification include the plural forms unless the context clearly indicates otherwise.

[0030] In this specification, the term "comprising" is used to indicate that it may include other components rather than excluding other components, unless there is a specific statement to the contrary.

[0031] In addition, unless otherwise specified in the specification of the present disclosure, the unit "%" means "wt%".

[0032] Unless otherwise defined, all terms, including technical and scientific terms, used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Pre-defined terms are to be interpreted as having a meaning consistent with the relevant technical literature and the present disclosure.

[0033] First, the alloy composition of the steel sheet according to an embodiment of the present disclosure will be

described. The content of the alloy composition means wt% unless otherwise specified.

Carbon (C): 0.05% to 0.18%

5 **[0034]** Carbon (C) is an element added to strengthen the transformation structure, which promotes high strength and facilitates the formation of martensite in complex-phase steel. If the content of C is less than 0.05%, it may be difficult to secure the desired level of strength. For example, as the content of C increases, the fraction of martensite in the steel may increase. If the content of C exceeds 0.18%, the strength of martensite increases, but the strength difference with ferrite, which has a low carbon concentration, may increase. In this case, due to the strength difference, fracture easily occurs at the interphase boundary when stress is applied, which may lead to a decrease in bendability. In addition, if the content of C exceeds 0.18%, weldability is poor, and welding defects may occur during part forming. That is, the content of C may be 0.05% to 0.18%, more specifically 0.06% to 0.17%, and even more specifically 0.07% to 0.15%.

15 Silicon (Si): 0.1% or less

[0035] Silicon (Si) is a ferrite stabilizing element, which can contribute to martensite formation by promoting ferrite transformation and encouraging C enrichment in untransformed austenite. In addition, since Si has excellent solid-solution strengthening ability, it can increase the strength of ferrite to reduce the hardness difference between phases, and can play a role in securing strength without deteriorating the ductility of the steel sheet. If the content of Si exceeds 0.1%, it may cause surface scale defects, leading to poor plating surface quality, or cause liquid metal embrittlement during spot welding of plated materials. That is, the content of Si may be 0.1% or less, specifically 0.10% or less, more specifically 0.08% or less, and even more specifically 0.05% or less. In addition, although it is not necessary to particularly limit the lower limit of the Si content, as a non-limiting example, the Si content may be more than 0%, may be 0.001% or more, and may be 0.002% or more.

Manganese (Mn): 1.0% to 2.3%

30 **[0036]** Manganese (Mn) refines grains without deteriorating ductility, prevents hot shortness caused by the formation of FeS by precipitating S in the steel as MnS, and can strengthen the steel. In addition, Mn can play a role in facilitating the formation of martensite by reducing the critical cooling rate at which martensite is obtained in complex-phase steel. If the content of Mn is less than 1.0%, it may be difficult to secure the target strength. If the content of Mn exceeds 2.3%, weldability, hot rollability, etc. may be deteriorated, or martensite may be excessively formed, leading to deterioration of material properties (e.g., bendability, elongation), or Mn-bands (bands of Mn oxides) may form in the structure, increasing the risk of processing cracks and sheet fractures. In addition, if the content of Mn exceeds 2.3%, Mn oxides may be eluted to the surface during annealing, which may significantly impair platability. That is, the content of Mn may be 1.0% to 2.3%, more specifically 1.3% to 2.2%, and even more specifically 1.6% to 2.0%.

Soluble Aluminum (sol.Al): 1.0% or less

40 **[0037]** Aluminum (Al) is added for grain refinement and deoxidation of steel, and as a ferrite stabilizing element, it can improve the hardenability of martensite by partitioning C in ferrite to austenite. In addition, Al can improve the ductility of the steel sheet by suppressing the precipitation of carbides in bainite when held at a constant temperature in the bainite transformation region. If the content of Al exceeds 1.0%, it is advantageous for increasing strength through the grain refinement effect, but it may cause surface defects of the plated steel sheet due to excessive formation of inclusions during the steelmaking and continuous casting process, or may cause a problem of increasing manufacturing costs. That is, the content of Al may be 1.0% or less, more specifically 0.8% or less, and even more specifically 0.5% or less. In addition, although it is not necessary to particularly limit the lower limit of the Al content, as a non-limiting example, the Al content may be more than 0%, may be 0.01% or more, and may be 0.02% or more.

50 Chromium (Cr): 0.1% to 1.0%

[0038] Chromium (Cr) may be included to improve the hardenability of steel and secure high strength. In addition, Cr is an element that plays an important role in the formation of martensite, and can be advantageous for manufacturing complex-phase steel with high ductility by minimizing the decrease in elongation relative to the increase in strength. Specifically, Cr-based carbides such as Cr_{23}C_6 are formed during the hot rolling process, and some of these carbides are dissolved during the annealing process, while others may remain undissolved. Accordingly, Cr can control the content of dissolved C in martensite after cooling to an appropriate level or less, which can be advantageous for

manufacturing complex-phase steel with a low yield ratio by suppressing the occurrence of yield point elongation (YP-EI).

[0039] If the content of Cr is less than 0.1%, the above-mentioned effects cannot be sufficiently obtained. If the content of Cr exceeds 1.0%, not only are the above-mentioned effects saturated, but there may also be a problem of deterioration in cold rollability due to an excessive increase in hot-rolled strength. In addition, if the content of Cr exceeds 1.0%, the fraction of Cr-based carbides increases and they become coarser, which can cause the martensite size to become coarser after annealing, leading to a decrease in elongation. That is, the content of Cr may be 0.1% to 1.0%, more specifically 0.1% to 0.9%, and even more specifically 0.2% to 0.8%.

Niobium (Nb): 0.05% or less

[0040] Niobium (Nb) segregates at austenite grain boundaries, suppresses the coarsening of austenite grains during annealing heat treatment, and can contribute to an increase in strength by forming fine carbides. If the content of Nb exceeds 0.05%, coarse carbides are precipitated, strength and elongation may be reduced due to a decrease in the amount of carbon in the steel, and a problem of increased manufacturing costs may occur. That is, the content of Nb may be 0.05% or less, specifically 0.050% or less, more specifically 0.045%, and even more specifically 0.040% or less. In addition, although it is not necessary to particularly limit the lower limit of the Nb content, as a non-limiting example, the Nb content may be more than 0%, may be 0.001% or more, and may be 0.002% or more.

Titanium (Ti): 0.05% or less

[0041] Titanium (Ti) is an element that forms fine carbides and can contribute to securing yield strength and tensile strength. In addition, Ti is an element that forms nitrides, and can suppress the precipitation of AlN by precipitating N in the steel as TiN, thereby reducing the risk of cracks during continuous casting. If the content of Ti exceeds 0.05%, coarse carbides are precipitated, strength and elongation may be reduced due to a decrease in the amount of carbon in the steel, and it may cause nozzle clogging during continuous casting. That is, the content of Ti may be 0.05% or less, more specifically 0.04% or less, and even more specifically 0.03% or less. In addition, although it is not necessary to particularly limit the lower limit of the Ti content, as a non-limiting example, the Ti content may be more than 0%, may be 0.001% or more, and may be 0.002% or more.

Phosphorus (P): 0.1% or less

[0042] Phosphorus (P) is a substitutional element that has a solid-solution strengthening effect, and can play a role in improving in-plane anisotropy and securing strength without significantly impairing formability. If the content of P exceeds 0.1%, the possibility of brittle fracture increases excessively, which may cause sheet fracture of the slab during hot rolling or impair the surface properties of the plating. That is, the content of P may be 0.1% or less, specifically 0.10% or less, more specifically 0.08% or less, and even more specifically 0.05% or less. In addition, although it is not necessary to particularly limit the lower limit of the P content, as a non-limiting example, considering the case of inevitable addition, the P content may be more than 0% and may be 0.001% or more.

Sulfur (S): 0.01% or less

[0043] Sulfur (S) is an impurity element that is inevitably added to steel and can deteriorate ductility and weldability, so controlling the S content to a low level can be effective in securing the physical properties of the steel sheet. If the content of S exceeds 0.01%, ductility and weldability may be deteriorated, or in particular, the possibility of causing red shortness may increase. That is, the content of S may be 0.01% or less, specifically 0.010% or less, more specifically 0.008% or less, and even more specifically 0.005% or less. In addition, although it is not necessary to particularly limit the lower limit of the S content, as a non-limiting example, considering the case of inevitable addition, the S content may be more than 0% and may be 0.001% or more.

Nitrogen (N): 0.01% or less

[0044] Nitrogen (N) can have an effective action in stabilizing austenite. If the content of N exceeds 0.01%, there may be a problem of a sharp increase in the refining cost of the steel. In addition, if the content of N exceeds 0.01%, the risk of cracks due to the formation of AlN or the like during continuous casting may increase. That is, the content of N may be 0.01% or less, specifically 0.010% or less, more specifically 0.008% or less, and even more specifically 0.005% or less. In addition, although it is not necessary to particularly limit the lower limit of the N content, as a non-limiting example, considering the case of inevitable addition, the N content may be more than 0% and may be 0.001%

or more.

[0045] The steel sheet according to an embodiment of the present disclosure may include the above-mentioned components and iron (Fe) as the remaining component. In addition, in a normal manufacturing process, unintended impurities from raw materials or the surrounding environment may be inevitably incorporated, so these cannot be excluded. For example, elements that may be included in the steel may be further included in a total amount of 1.0% or less. Since these impurities are known to any person skilled in the art of the normal manufacturing process, all of their contents are not particularly mentioned in this specification.

[0046] The steel sheet according to an embodiment of the present disclosure may have a T value of 1380 or more and less than 1648, as defined by Equation 1 below.

[Equation 1]

$$T = 279 \times [C] + 711 \times [Mn] + 474 \times [Nb] + 177 \times [Ti] - 75 \times [Cr]$$

(In Equation 1, [C], [Mn], [Nb], [Ti], and [Cr] represent the content (wt%) of each element.)

[0047] Equation 1 is an equation that quantitatively expresses that the alloying elements contained in the steel sheet can contribute to the strength and bendability of the steel sheet. The contents of C, Mn, Nb, Ti, and Cr components among the alloying elements contained in the steel sheet can be adjusted to satisfy Equation 1 below. By adjusting the contents of the alloying elements in this way, the strength and bendability of the steel sheet can be secured at a desired level.

[0048] Specifically, C and Mn can increase the strength of the steel sheet through the solid-solution strengthening effect of the steel. At this time, the contribution of each element to the strength of the steel sheet is different, and the constant value multiplied by each component in Equation 1 can relatively represent the degree of contribution of each element to the strength.

[0049] Nb and Ti have a precipitation strengthening effect and can contribute to an improvement in strength. In addition, Nb and Ti are precipitated in the ferrite matrix in DP steel and have a ferrite strengthening effect, and can improve the bendability of the steel sheet by reducing the hardness difference between the ferrite and martensite phases. Therefore, in Equation 1, the constant value multiplied by the contents of Nb and Ti can be expressed as a positive value.

[0050] Among the above elements, Cr has the smallest solid-solution strengthening effect and can greatly increase hardenability, and if added in an excessive amount, a large amount of martensite is formed, which may lead to a decrease in bendability. Therefore, in Equation 1, the value of the constant multiplied by the content of Cr can be expressed as a negative value.

[0051] If the T value defined in Equation 1 is less than 1380, a problem may occur in that fresh martensite is excessively formed in the continuous annealing process, making it impossible to secure the target strength and bendability characteristics of the steel sheet. Although it is not necessary to particularly limit the upper limit of the T value, if the T value is 1648 or more, it means that the alloying elements are included in an excessive amount, which may cause a problem in that the strength increases excessively, or the bendability or elongation cannot reach the target level. That is, the T value may be 1380 or more and less than 1648, more specifically 1380 to 1600, and even more specifically 1380 to 1500.

[0052] The steel sheet according to an embodiment of the present disclosure may have an RT value of 0.01 or more as defined by Equation 2 below.

[Equation 2]

$$RT = [Si] + [Nb] + [Ti]$$

(In Equation 2, [Si], [Nb], and [Ti] represent the content (wt%) of each element.)

[0053] Generally, when a large amount of Si is added, there may be problems such as dent defects of the steel sheet in the annealing furnace, poor phosphatability of the cold-rolled steel sheet, and deterioration of liquid metal embrittlement and platability of the plated steel sheet. The steel sheet according to an embodiment of the present disclosure is characterized in that it can solve the above-mentioned problems by minimizing the content of Si. If the content of Si is reduced, the mechanical properties may be deteriorated. Therefore, in consideration of this, by controlling the contents of Nb and Ti, deterioration of the mechanical properties can be prevented through carbide precipitation. That is, by appropriately adjusting the RT value defined by Equation 2, problems caused by an excessive amount of Si can be minimized, and mechanical properties can be improved.

[0054] If the RT value defined in Equation 2 is less than 0.01, the desired level of physical properties cannot be secured. That is, the RT value may be 0.01 or more, more specifically 0.02 or more, and even more specifically 0.03 or more. In addition, although it is not necessary to particularly limit the upper limit of the RT value, the upper limit of the RT value may be 0.2, which is the same as the maximum addition in the limited range of each alloying element.

[0055] Hereinafter, the microstructure of the steel sheet according to an embodiment of the present disclosure will be described. The fraction of the microstructure means area% unless otherwise specified. In addition, the fraction of the microstructure can be measured by analyzing the matrix at a 1/4 thickness point of the steel sheet, and specifically, the fraction of the microstructure can be measured using FE-SEM, an Image analyzer, and XRD.

[0056] For example, the microstructure of the steel sheet may include 65% to 85% of ferrite, 10% or less of bainite, 6% to 20% of fresh martensite, and 5% or less of retained austenite.

[0057] Ferrite is a soft structure and can contribute to the ductility of the steel sheet. If the area fraction of ferrite relative to the total microstructure included in the steel sheet is less than 65%, it may be difficult to secure the target bendability. If the area fraction of ferrite exceeds 85%, it may be difficult to secure the desired level of strength. That is, the area fraction of ferrite may be 65% to 85%, more specifically 68% to 83%, and even more specifically 73% to 83%.

[0058] Bainite is a structure with an intermediate hardness between ferrite and martensite, and by including bainite in the area fraction of the above range, the ductility and hardness of the steel sheet can be adjusted to a target level. If the area fraction of bainite relative to the total microstructure included in the steel sheet exceeds 10%, the strength may be reduced. That is, the area fraction of bainite may be 10% or less, more specifically 9% or less, and even more specifically 8% or less. In addition, although it is not necessary to particularly limit the lower limit of the area fraction of bainite, as a non-limiting example, the area fraction of bainite may be more than 0%, may be 1% or more, and may be 2% or more.

[0059] Fresh martensite can contribute to an increase in the strength of the steel sheet. If the area fraction of fresh martensite relative to the total microstructure included in the steel sheet is less than 6%, the target strength cannot be secured. In addition, if the area fraction of fresh martensite exceeds 20%, the area fraction of bainite relatively decreases, which may cause a problem of deterioration in bendability. That is, the area fraction of fresh martensite may be 6% to 20%, more specifically 8% to 18%, and even more specifically 9% to 17%.

[0060] Retained austenite may be formed in a small amount during the final cooling process. If the area fraction of retained austenite relative to the total microstructure included in the steel sheet exceeds 5%, it may be vulnerable to liquid metal embrittlement during spot welding. That is, the area fraction of retained austenite may be 5% or less, more specifically 4% or less, and even more specifically 3% or less. In addition, although it is not necessary to particularly limit the lower limit of the area fraction of retained austenite, as a non-limiting example, the area fraction of retained austenite may be more than 0%, may be 0.1% or more, and may be 0.3% or more.

[0061] For example, the steel sheet may further include a galvanized layer or a galvanized layer on its surface. The galvanized layer and/or the galvanized layer may be provided on at least one surface of the steel sheet to improve the corrosion resistance of the steel sheet.

[0062] The galvanized layer may be composed of any one selected from zinc and zinc-based alloys. For example, when composed of a zinc-based alloy, the plating layer may include one or more selected from aluminum (Al), magnesium (Mg), nickel (Ni), and iron (Fe), and zinc (Zn) as a remainder. However, the composition of the galvanized layer is not limited thereto, and may have a composition commonly used in the art.

[0063] The galvanized layer may be formed by hot-dip galvanizing at least one surface of the steel sheet. However, the plating method is not limited thereto, and methods commonly used in the art, such as electroplating, vacuum deposition plating, and cladding methods, may be applied.

[0064] The galvanized layer is obtained by thermal diffusion into the galvanized layer and may be provided on a cross-section or both surfaces of the steel sheet. Specifically, the galvanized layer can be obtained by heat-treating the galvanized layer so that the galvanized layer and some alloy components of the steel sheet are alloyed.

[0065] In the steel sheet according to an embodiment of the present disclosure, sufficient strength and bendability of the steel sheet can be secured by controlling the components such that the T value defined in Equation 1 is 1380 or more and less than 1648, and the RT value defined in Equation 2 is 0.01 or more, by adjusting the content of the alloying elements. In addition, in the steel sheet according to an embodiment of the present disclosure, by adjusting the type and area fraction of the microstructure, the ductility and hardness of the steel sheet can be secured at a target level, and the bendability of the steel sheet can be improved.

[0066] For example, the steel sheet may have a tensile strength (TS) of 590 MPa or more and an elongation (EI) of 20% or more. Additionally/alternatively, the steel sheet may satisfy Equation 3 below. That is, the steel sheet can secure excellent properties in strength and bendability by controlling the alloy composition and microstructure. In addition, a steel sheet with excellent strength and bendability has improved workability, can be used for complex shapes during press forming, and can be suitably utilized for automotive structural members.

[Equation 3]

$$A/TH \geq 60 \text{ (}^\circ/\text{mm)}$$

(In Equation 3, A represents the bending angle ($^\circ$) at which no cracks occur in the bent portion during a 180° bending test, and TH represents the thickness (mm) of the steel sheet.)

[0067] Hereinafter, a method for manufacturing a steel sheet according to an embodiment of the present disclosure will be described in detail. However, this does not mean that the method for manufacturing a steel sheet according to the present disclosure must be manufactured by the following manufacturing method.

[Slab Reheating Step]

[0068] A steel slab having the aforementioned composition can be reheated. Through reheating, the subsequent rolling process can be smoothly performed, and the desired physical properties of the steel sheet can be sufficiently secured. At this time, the composition of the steel slab is the same as the composition of the aforementioned steel sheet, and the description of the aforementioned steel sheet can be applied equally to the reasons for adding each component and limiting the content thereof in the slab.

[0069] For example, the reheating step may be performed at 1,100°C to 1,300°C. If the reheating temperature is less than 1,100°C, the re-dissolution of precipitation elements such as Nb and Ti decreases, and the effect of adding these elements may also be reduced. In addition, if the reheating temperature exceeds 1,300°C, the process cost may increase, or a large amount of hot-rolled oxide may be generated, leading to a deterioration in the surface quality of the steel sheet. That is, the reheating temperature may be 1,100°C to 1,300°C, more specifically 1,120°C to 1,250°C, and even more specifically 1,150°C to 1,240°C. However, the reheating temperature is not limited thereto, and normal reheating conditions can be applied within a range that does not impair the effects of the present disclosure.

[Hot-Rolled Steel Sheet Obtaining Step]

[0070] A hot-rolled steel sheet can be obtained by hot-rolling the slab reheated in the aforementioned step at a normal hot-rolling temperature. Through hot rolling, a hot-rolled steel sheet in which carbides are finely dispersed can be manufactured, and these carbides can become regions for austenite nucleation. By uniformly dispersing fine carbides in the hot-rolling process, the austenite generated as the carbides dissolve in the annealing process can be finely dispersed. Accordingly, the martensite generated during cooling after annealing can be finely and uniformly dispersed, which can contribute to the improvement of the strength and elongation of the finally manufactured steel sheet.

[0071] For example, the step of obtaining the hot-rolled steel sheet may be performed at a finish rolling temperature of 800°C to 950°C. If the finish rolling temperature is less than 800°C, there may be a problem of an increase in the hot-rolling load due to the low hot-rolling temperature. In addition, if the finish rolling temperature exceeds 950°C, the crystal grains become coarse, reducing the strength of the steel sheet, and there may be a problem in that the surface quality of the steel sheet deteriorates due to an increase in hot-rolled oxide on the surface layer. That is, the finish rolling temperature may be 800°C to 950°C, more specifically 830°C to 940°C, and even more specifically 850°C to 920°C.

[Coiling Step]

[0072] The hot-rolled steel sheet obtained in the aforementioned step can be coiled. For example, the coiling temperature may be 400°C to 700°C. If the coiling temperature is less than 400°C, a large amount of low-temperature transformation structures such as martensite or bainite are generated, and the strength of the hot-rolled steel sheet increases excessively, which may cause a problem of rolling load in the cold-rolling process. In addition, if the coiling temperature exceeds 700°C, the microstructure becomes coarse, reducing the strength of the finally annealed steel sheet, and the surface quality and platability of the steel sheet may be deteriorated due to an increase in oxides on the surface of the steel sheet. That is, the coiling temperature may be 400°C to 700°C, more specifically 450°C to 680°C, and even more specifically 500°C to 650°C.

[0073] For example, in the coiling step, after coiling the hot-rolled steel sheet, it can be cooled to room temperature at an average cooling rate of 0.1°C/s or less. If the average cooling rate exceeds 0.1°C/s, a rolling load may occur in the cold-rolling process due to the excessive generation of low-temperature transformation structures. In addition, if the average cooling rate exceeds 0.1°C/s, the shape of the hot-rolled steel sheet deteriorates due to the fast cooling rate, and sheet fracture may occur in the cold-rolling process. That is, the average cooling rate may be 0.1°C/s or less,

specifically 0.10°C/s or less, more specifically 0.08°C/s or less, and even more specifically 0.07°C/s or less. In addition, although it is not necessary to particularly limit the lower limit of the average cooling rate, as a non-limiting example, the average cooling rate may be more than 0°C/s, may be 0.01°C/s or more, and may be 0.02°C/s or more.

5 [Cold-Rolled Steel Sheet Obtaining Step]

[0074] A cold-rolled steel sheet can be obtained by cold-rolling the hot-rolled steel sheet coiled in the aforementioned step. For example, the cold rolling may be performed with a reduction ratio of 40% to 70%. If the reduction ratio is less than 40%, it is not only difficult to secure the target thickness, but it may also be difficult to correct the shape of the steel sheet. In addition, if the reduction ratio exceeds 70%, the possibility of cracks occurring at the edge of the steel sheet increases, or there may be a problem involving a rolling load in the cold-rolling process. That is, the reduction ratio may be 40% to 70%, more specifically 45% to 65%, and even more specifically 45% to 60%.

[0075] For example, a step of pickling the coiled hot-rolled steel sheet may be further included before performing cold rolling. Through the pickling treatment, the oxide layer formed on the surface of the steel sheet can be removed. The method of pickling treatment is not particularly limited, and a method commonly used in the art (for example, immersing the steel sheet in a hydrochloric acid bath) can be applied.

[Continuous Annealing Step]

[0076] The cold-rolled steel sheet obtained in the aforementioned step can be continuously annealed by heating it to an annealing temperature (T1) within a predetermined range, cooling it to a cooling-end temperature (T2) within a predetermined range, and then holding it at a constant temperature. Continuous annealing can be performed to form ferrite and austenite simultaneously with recrystallization and to partition carbon.

[0077] In the continuous annealing step, the annealing temperature (T1) may be 800°C to 850°C. By controlling the annealing temperature (T1) within the above range, the fractions of dual-phase austenite and ferrite in the steel sheet are determined, and the strength of the annealed steel sheet can be differently adjusted by the determined fractions. Generally, as the fraction of dual-phase austenite increases, the strength of the annealed steel sheet may increase, but since the subsequent process also affects the microstructure, the physical properties of the finally manufactured steel sheet may vary.

[0078] If the annealing temperature (T1) is less than 800°C, not only is sufficient recrystallization not achieved, but it is also difficult to form sufficient dual-phase austenite, making it impossible to secure the desired levels of martensite and bainite fractions after annealing. In addition, if the annealing temperature (T1) is less than 800°C, ferrite is formed at a high fraction, making it difficult to secure the desired level of mechanical properties (e.g., strength, elongation, bendability, etc.).

[0079] If the annealing temperature (T1) exceeds 850°C, productivity may decrease, or austenite may be excessively formed, leading to a significant increase in the fractions of bainite and martensite after cooling, which may result in an increase in yield strength and a decrease in ductility. In addition, if the annealing temperature (T1) exceeds 850°C, surface enrichment by elements (e.g., Si, Mn, or B) that deteriorate the wettability of hot-dip galvanizing becomes severe, which may lead to a deterioration in the quality of the plated surface. That is, the annealing temperature (T1) during continuous annealing may be 800°C to 850°C, more specifically 810°C to 840°C, and even more specifically 810°C to 830°C.

[0080] In the continuous annealing step, the cooling-end temperature (T2) may be 450°C to 600°C. Through cooling of the heated steel sheet, the dual-phase austenite in the steel sheet can be transformed into ferrite. At this time, by adjusting the cooling-end temperature (T2) within the above range, the fraction of ferrite transformed from the dual-phase austenite can be differently adjusted.

[0081] During continuous annealing, if the cooling-end temperature (T2) is less than 450°C, the fraction of bainite may increase excessively during the isothermal holding process and the formation of martensite may decrease, leading to a problem of deterioration in strength. In addition, if the cooling-end temperature (T2) exceeds 600°C, a large amount of ferrite transformation may occur, which may cause a problem of a decrease in strength. That is, the cooling-end temperature (T2) may be 450°C to 600°C, more specifically 470°C to 580°C, and even more specifically 480°C to 570°C.

[0082] In the continuous annealing step, cooling to the cooling-end temperature (T2) may be performed at an average cooling rate of 20°C/s or less. If the average cooling rate exceeds 20°C/s, material deviation within the steel sheet may increase due to non-uniform cooling, and a problem of deterioration in the sheet shape may occur. That is, the average cooling rate may be 20°C/s or less, more specifically 18°C/s or less, and even more specifically 16°C/s or less. In addition, although it is not necessary to particularly limit the lower limit of the average cooling rate, as a non-limiting example, the average cooling rate may be more than 0°C/s, may be 1°C/s or more, and may be 3°C/s or more.

[0083] In the continuous annealing step, after cooling to the cooling-end temperature (T2), the cold-rolled steel sheet

may be held at the cooling-end temperature (T2) for 50 seconds or more. If the isothermal holding time is less than 50 seconds, martensite may be excessively formed, leading to a decrease in bendability. That is, the isothermal holding time may be 50 seconds or more, more specifically 60 seconds or more, and even more specifically 70 seconds or more. In addition, although it is not necessary to particularly limit the upper limit of the isothermal holding time, as a non-limiting example, the upper limit of the isothermal holding time may be 500 seconds, and may be 400 seconds.

[0084] In the continuous annealing step, the R value defined in Equation 4 below may be 1,543 to 1,590.

$$R = 174 \times [C] + 680 \times [Mn] + 370 \times [Nb] + 177 \times [Ti] - 86 \times [Cr] + 0.33 \times [T1] - 0.05 \times [T2] \quad [\text{Equation 4}]$$

(In Equation 4, [C], [Mn], [Nb], [Ti], and [Cr] represent the content (wt%) of each element, and [T1] and [T2] represent the annealing temperature (°C) and the cooling-end temperature (°C) in the continuous annealing step, respectively.)

[0085] Equation 4 is an equation that quantitatively expresses that both strength and bendability can be secured by adjusting the content of the alloying elements of the steel slab and the annealing conditions in the continuous annealing step. Specifically, by optimizing the contents of C, Mn, Nb, Ti, and Cr components and the conditions of the annealing temperature (T1) and the cooling-end temperature (T2) in the continuous annealing step, strength and bendability can be secured at a target level.

[0086] Specifically, in Equation 4, T1 represents the annealing temperature in the continuous annealing step. The fractions of dual-phase austenite and ferrite in the steel sheet are determined by T1, and the strength of the annealed steel sheet can be differently adjusted by the determined fractions. Generally, as the fraction of dual-phase austenite increases, the strength of the annealed steel sheet may increase, but since the subsequent process also affects the microstructure, the physical properties of the finally manufactured steel sheet may vary.

[0087] In Equation 4, T2 represents the cooling-end temperature in the continuous annealing step. In the subsequent cooling process, the dual-phase austenite can undergo additional transformation into ferrite depending on T2, so the fraction of ferrite can be differently adjusted, which can affect the physical properties of the steel sheet. In addition, the fractions of bainite, retained austenite, and martensite, which are the microstructures of the annealed steel sheet, can be differently adjusted depending on T2.

[0088] For example, if T2 is higher than the bainite transformation start temperature or lower than the martensite transformation start temperature, bainite cannot be introduced into the structure of the steel sheet. That is, T2 should be set to a temperature between the bainite transformation start temperature and the martensite transformation start temperature.

[0089] T1 and T2, together with the alloying elements of the steel sheet, affect the microstructure of the annealed steel sheet and, consequently, can affect the physical properties of the steel sheet. That is, in order to secure the target physical properties, Equation 4, which is optimized for this, must be satisfied. Through this, it is possible to secure the target level of strength even with a minimized Si content in the steel slab, and to manufacture a high-tensile-strength steel sheet with excellent bendability.

[0090] If the R value defined in Equation 4 is less than 1,543, it is difficult to secure the microstructure at a desired level, for example, due to excessive formation of ferrite or a large amount of martensite, and the strength of the steel sheet may be reduced. In addition, if the R value exceeds 1,590, it is difficult to secure the microstructure at a desired level, for example, due to the formation of a small amount of ferrite or excessive formation of bainite, and it may be difficult to secure the bendability of the steel sheet. That is, the R value may be 1,543 to 1,590, more specifically 1,543 to 1,580, and even more specifically 1,543 to 1,578.

[0091] For example, after the continuous annealing step, the continuously annealed steel sheet can be galvanized. Through the galvanizing step, a galvanized layer can be formed on the surface of the steel sheet. For example, the galvanizing step can be performed by immersing the continuously annealed steel sheet in a hot-dip galvanizing bath. However, the present disclosure is not limited thereto, and galvanizing can be performed under normal conditions applicable in the art.

[0092] The galvanizing step may be performed at 430°C to 490°C. If the plating temperature is less than 430°C, sufficient wettability within the contact interface between the steel sheet and zinc may not be secured. In addition, if the plating temperature exceeds 490°C, an excessive reaction between the steel sheet and zinc occurs, forming an Fe-Zn alloy phase at the interface, which may lead to a decrease in the adhesion of the plating. That is, the plating temperature may be 430°C to 490°C, more specifically 440°C to 480°C, and even more specifically 450°C to 470°C.

[0093] For example, after the galvanizing step, a step of alloying heat treatment of the plated steel sheet may be further included. Through the alloying heat treatment step, some alloy components of the steel sheet are diffused into the galvanized layer, whereby a galvannealed layer can be formed on the surface of the steel sheet.

[0094] The alloying heat treatment step may be performed at 460°C to 530°C. If the alloying heat treatment temperature is less than 460°C, the amount of Fe diffusion is small, resulting in insufficient alloying degree, which may lead to a deterioration in the plating properties. In addition, if the alloying heat treatment temperature exceeds 530°C, a powdering problem may occur due to excessive alloying. That is, the alloying temperature may be 460°C to

530°C, more specifically 470°C to 520°C, and even more specifically 480°C to 520°C.

[Cooling Step]

[0095] The continuously annealed steel sheet from the aforementioned step can be cooled to room temperature. Additionally/alternatively, if a galvanizing step has been additionally performed, the galvanized steel sheet can be cooled to room temperature. Additionally/alternatively, if an alloying heat treatment step has been additionally performed, the alloying heat-treated steel sheet can be cooled to room temperature. In the cooling step, the cooling conditions are not particularly limited, and a method commonly used in the art (for example, air cooling) can be applied.

[0096] The method for manufacturing a steel sheet according to an embodiment of the present disclosure can appropriately control the type and area fraction of the microstructure of the steel sheet by adjusting the content of alloying elements and the conditions in the continuous annealing step. Accordingly, the ductility and hardness of the steel sheet can be secured at a target level, and the bendability of the steel sheet can be improved.

[0097] For example, a steel sheet manufactured by the aforementioned manufacturing method may have a tensile strength (TS) of 590 MPa or more and an elongation (EI) of 20% or more. Additionally/alternatively, the steel sheet may satisfy Equation 3 below. That is, the steel sheet can secure excellent strength and bendability by controlling the alloy composition and annealing conditions. In addition, a steel sheet with excellent strength and bendability has improved workability, can be used for complex shapes during press forming, and can be suitably utilized for automotive structural members.

[Equation 3]

$$A/TH \geq 60 \text{ (}^\circ/\text{mm)}$$

(In Equation 3, A represents the bending angle (°) at which no cracks occur in the bent portion during a 180° bending test, and TH represents the thickness (mm) of the steel sheet.)

Mode for Invention

[0098] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the following examples are only for illustrating the present disclosure in more detail and are not intended to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and matters reasonably inferred therefrom.

(Example)

[0099] A steel slab having the composition shown in Table 1 below (remaining components of the alloy composition: Fe and inevitable impurities) was manufactured, then reheated under the conditions of Table 2 below, and finish hot-rolled to obtain a hot-rolled steel sheet. The hot-rolled steel sheet was coiled under the conditions of Table 2 below and cooled to room temperature, then pickled and cold-rolled with a reduction ratio of 50% to obtain a cold-rolled steel sheet with a thickness of 1.2 mm. Thereafter, as shown in Table 2 below, the cold-rolled steel sheet was heated to an annealing temperature (T1), cooled to a cooling-end temperature (T2), and then held at a constant temperature for 50 seconds or more to obtain a steel sheet. Finally, the steel sheet was hot-dip galvanized at a temperature of 460°C (composition of the plating bath was Al: 0.2%, Mg: 1%, and Zn: remainder) and cooled to room temperature.

[Table 1]

Steel Grade	Alloy Composition (wt%)										Equation 1	Equation 2
	C	Si	Mn	Sol. Al	Nb	Ti	Cr	P	S	N		
A	0.13	0.01	1.9	0.04	0.02	0	0.2	0.008	0.002	0.004	1382	0.03
B	0.07	0.02	2	0.04	0.02	0	0.5	0.007	0.002	0.004	1414	0.04
C	0.15	0	1.9	0.04	0	0	0.2	0.006	0.002	0.004	1378	0
D	0.15	0.03	1.9	0.04	0	0.02	0.2	0.008	0.002	0.004	1381	0.05
E	0.11	0.03	1.9	0.04	0.04	0	0.2	0.008	0.002	0.004	1386	0.07
F	0.13	0	1.9	0.04	0.04	0.02	0.2	0.007	0.002	0.004	1395	0.06
G	0.15	0.08	2.25	0.04	0.04	0.02	0.2	0.007	0.002	0.003	1649	0.14
[Equation 1] $T = 279 \times [C] + 711 \times [Mn] + 474 \times [Nb] + 177 \times [Ti] - 75 \times [Cr]$												
(In Equation 1, [C], [Mn], [Nb], [Ti], and [Cr] represent the content (wt%) of each element.)												
[Equation 2]												
$RT = [Si] + [Nb] + [Ti]$												
(In Equation 2, [Si], [Nb], and [Ti] represent the content (wt%) of each element.)												

[Table 2]

Category	Steel Grade	Reheating Temp. (°C)	Finish Rolling Temp. (°C)	Coiling		Continuous Annealing		Equation 4
				Temp. (°C)	Cooling Rate (°C/s)	Annealing Temp. (T1, °C)	Cooling-end Temp. (T2, °C)	
Comp. Ex. 1	A	1210	905	610	0.05	770	520	1533
Comp. Ex. 2	A	1210	905	610	0.05	790	520	1540
Inv. Ex. 1	A	1210	905	610	0.05	810	520	1546
Inv. Ex. 2	A	1210	905	610	0.05	830	520	1553
Comp. Ex. 3	B	1198	899	605	0.03	770	520	1565
Inv. Ex. 3	B	1198	899	605	0.03	800	560	1573
Inv. Ex. 4	B	1198	899	605	0.03	810	560	1576
Inv. Ex. 5	B	1198	899	605	0.03	830	560	1582
Comp. Ex. 4	B	1198	899	605	0.03	850	450	1595
Comp. Ex. 5	C	1201	887	608	0.04	810	560	1540
Comp. Ex. 6	C	1201	887	608	0.04	830	560	1547
Inv. Ex. 6	D	1201	887	608	0.04	810	520	1546
Inv. Ex. 7	D	1201	887	608	0.04	830	520	1552
Inv. Ex. 8	D	1201	887	608	0.04	810	560	1544
Inv. Ex. 9	D	1201	887	608	0.04	830	560	1550
Inv. Ex. 10	E	1188	911	599	0.03	810	520	1550
Inv. Ex. 11	E	1188	911	599	0.03	830	520	1557
Comp. Ex. 7	F	1202	888	615	0.04	770	560	1542
Comp. Ex. 8	F	1202	888	615	0.04	790	560	1548
Inv. Ex. 12	F	1202	888	615	0.04	810	560	1555

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(continued)

Category	Steel Grade	Reheating Temp. (°C)	Finish Rolling Temp. (°C)	Coiling Temp. (°C)		Cooling Rate (°C/s)	Continuous Annealing		Equation 4	
							Annealing Temp. (T1, °C)	Cooling-end Temp. (T2, °C)		
Inv. Ex. 13	F	1202	888	615		0.04	830	560	1562	
Comp. Ex. 9	F	1202	888	615		0.04	830	400	1570	
Comp. Ex. 10	F	1202	888	615		0.04	870	560	1575	
Comp. Ex. 11	F	1202	888	615		0.04	830	630	1558	
Comp. Ex. 12	G	1208	890	605		0.04	830	560	1803	
[Equation 4] $R = 174 \times [C] + 680 \times [Mn] + 370 \times [Nb] + 177 \times [Ti] - 86 \times [Cr] + 0.33 \times [T1] - 0.05 \times [T2]$										
(In Equation 4, [C], [Mn], [Nb], [Ti], and [Cr] represent the content (wt%) of each element, and [T1] and [T2] represent the annealing temperature (°C) and the cooling-end temperature (°C) in the continuous annealing step, respectively.)										

[0100] For each steel sheet, the fraction of microstructure and mechanical properties (yield strength, tensile strength, elongation, and bendability) were measured, and the results are shown in Table 3.

[0101] In the case of the microstructure fraction, the matrix was analyzed at the 1/4 thickness point of each steel sheet, and the results were used. Specifically, the fractions of ferrite (F), bainite (B), fresh martensite (FM), and retained austenite (A) were measured using FE-SEM, an Image analyzer, and XRD.

[0102] Among the mechanical properties, for yield strength, tensile strength, and elongation, the room-temperature tensile properties were evaluated for each test piece in the L direction using the ASTM standard.

[0103] Among the mechanical properties, for bendability, a 180° bending test was performed on each test piece, and then the value obtained by dividing the bending angle (°) at which no crack occurred in the bent portion by the thickness (mm) of the test piece was measured and evaluated. Here, the bent portion may refer to the part of the steel sheet to which the bending angle is applied, and can generally refer to the part to which bending is applied.

[Table 3]

Category	Microstructure (area%)				Mechanical Properties			
	F	B	FM	A	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Bendability (°/mm)
Comp. Ex. 1	90	0	9	1	401	711	16.8	46
Comp. Ex. 2	88	0	11	1	389	728	17.0	45
Inv. Ex. 1	80	5	13	2	357	614	25.8	71
Inv. Ex. 2	82	3	14	1	368	604	29.0	72
Comp. Ex. 3	91	1	7	1	409	756	17.7	64
Inv. Ex. 3	83	0	15	2	366	599	25.3	85
Inv. Ex. 4	83	0	16	1	370	626	27.4	80
Inv. Ex. 5	78	5	16	1	367	628	29.3	81
Comp. Ex. 4	64	25	11	0	400	680	22.4	55
Comp. Ex. 5	72	6	21	1	369	699	21.6	56
Comp. Ex. 6	72	5	22	1	379	702	22.4	57
Inv. Ex. 6	81	7	10	2	344	628	26.1	66
Inv. Ex. 7	80	5	13	2	338	618	27.6	72
Inv. Ex. 8	82	3	14	1	365	604	29.2	71
Inv. Ex. 9	82	2	15	1	362	592	28.3	74
Inv. Ex. 10	81	5	12	2	360	635	29.5	66
Inv. Ex. 11	78	5	16	1	363	633	27.6	71
Comp. Ex. 7	91	0	9	0	392	721	18.8	51
Comp. Ex. 8	88	0	12	0	282	682	16.6	61
Inv. Ex. 12	82	5	12	1	353	637	26.2	72
Inv. Ex. 13	77	7	15	1	346	631	26.0	71
Comp. Ex. 9	76	18	5	1	383	567	19.8	81
Comp. Ex. 10	78	12	10	0	466	701	18.6	55
Comp. Ex. 11	79	13	7	1	401	711	17.8	58
Comp. Ex. 12	70	9	21	0	432	822	17.5	59

[0104] As shown in Table 3, in the case of Inventive Examples 1 to 13, which satisfy the alloy composition and manufacturing conditions of the present disclosure, the microstructure characteristics proposed in the present disclosure were satisfied, and the target physical properties could also be secured.

[0105] Representing the inventive examples, FIG. 1 shows a photograph of the microstructure of Inventive Example 13 according to an embodiment of the present disclosure, observed with an electron microscope.

[0106] Referring to FIG. 1, the relatively dark regions represent ferrite, and the relatively bright regions represent fresh martensite. That is, it was found that in Inventive Example 13, which satisfies the alloy composition and manufacturing conditions of the present disclosure, and in which the T value defined by Equation 1 was adjusted to be from 1380 to less than 1648, ferrite (F) and fresh martensite (FM) were formed with area fractions within the range of the examples.

[0107] On the other hand, in Comparative Examples 1 and 2, which had a low annealing temperature (T1) during continuous annealing and also a low value for Equation 4, the elongation and bendability were not secured to the desired level. This is understood to be because sufficient recrystallization did not occur due to the low values of the annealing temperature (T1) and Equation 4, and thus sufficient austenite could not be formed in the continuous annealing process.

[0108] In Comparative Example 3, which satisfied Equation 4 proposed in the present disclosure but had a low annealing temperature (T1), the fraction of ferrite was measured to be high, and the elongation was poor.

[0109] In Comparative Example 4, which satisfied the annealing temperature (T1) and cooling-end temperature (T2) conditions proposed in the present disclosure but had a high value for Equation 4, the area fraction of bainite was measured to be high, and the area fraction of ferrite was measured to be low. Accordingly, Comparative Example 4 failed to secure the bendability characteristic to the desired level.

[0110] In Comparative Examples 5 and 6, which did not satisfy Equations 1 and 2 proposed in the present disclosure, the area fraction of fresh martensite was measured to be high, and accordingly, the bendability was poor.

[0111] In Comparative Examples 7 and 8, which had a low annealing temperature (T1), the recrystallization of ferrite was insufficient and the area fraction of ferrite was measured to be high, and accordingly, the elongation was reduced.

[0112] In Comparative Example 9, which had a low cooling-end temperature (T2), the area fraction of bainite was measured to be high, and the area fraction of martensite was measured to be low, and therefore the strength was not secured to the desired level.

[0113] In Comparative Example 10, which had a high annealing temperature (T1), and Comparative Example 11, which had a high cooling-end temperature (T2), the fraction of bainite was excessive, leading to a decrease in elongation and bendability.

[0114] In Comparative Example 12, which did not satisfy Equation 1 proposed in the present disclosure, the fraction of fresh martensite was excessive, and the elongation and bendability were poor.

[0115] Representing the comparative examples, FIG. 2 shows a photograph of the microstructure of Comparative Example 6 according to an embodiment of the present disclosure, observed with an electron microscope.

[0116] Referring to FIG. 2, the relatively dark regions represent ferrite, and the relatively bright regions represent fresh martensite. That is, it can be confirmed that in Comparative Example 6, since Equations 1 and 2 proposed in the present disclosure were not satisfied, martensite was excessively formed.

[0117] The above-described embodiments are merely examples, and the present disclosure is not limited thereto. Anything that has a substantially identical configuration and achieves the same operational effects 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 steel sheet, comprising, by weight%: 0.05% to 0.18% of carbon (C), 0.1% or less of silicon (Si), 1.0% to 2.3% of manganese (Mn), 1.0% or less of soluble aluminum (sol.Al), 0.1% to 1.0% of chromium (Cr), 0.05% or less of niobium (Nb), 0.05% or less of titanium (Ti), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), 0.01% or less of nitrogen (N), a remainder of iron (Fe), and other inevitable impurities,

wherein a T value defined by Equation 1 below is 1380 or more and less than 1648, and a microstructure comprises, by area%, 65% to 85% of ferrite, 10% or less of bainite, 6% to 20% of fresh martensite, and 5% or less of retained austenite.

[Equation 1]

$$T = 279 \times [C] + 711 \times [Mn] + 474 \times [Nb] + 177 \times [Ti] - 75 \times [Cr]$$

(wherein, in Equation 1, [C], [Mn], [Nb], [Ti], and [Cr] represent a content (wt%) of each element.)

2. The steel sheet of claim 1,

wherein an RT value defined by Equation 2 below is 0.01 or more.

[Equation 2]

$$RT = [Si] + [Nb] + [Ti]$$

(wherein, in Equation 2, [Si], [Nb], and [Ti] represent a content (wt%) of each element.)

3. The steel sheet of claim 1,

wherein the steel sheet has a tensile strength of 590 MPa or more and an elongation of 20% or more.

4. The steel sheet of claim 1,

wherein the steel sheet satisfies Equation 3 below:

$$[Equation 3] \quad A/TH \geq 60 \text{ (}^\circ/\text{mm)}$$

(wherein, in Equation 3, A represents a bending angle (°) at which no crack occurs in a bent portion in a 180° bending test, and TH represents a thickness (mm) of the steel sheet.)

5. The steel sheet of claim 1,

wherein the steel sheet further comprising a galvanized layer or a galvanized layer on a surface thereof.

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

reheating a steel slab comprising, by weight%, 0.05% to 0.18% of carbon (C), 0.1% or less of silicon (Si), 1.0% to 2.3% of manganese (Mn), 1.0% or less of soluble aluminum (sol.Al), 0.1% to 1.0% of chromium (Cr), 0.05% or less of niobium (Nb), 0.05% or less of titanium (Ti), 0.1% or less of phosphorus (P), 0.01% or less of sulfur (S), 0.01% or less of nitrogen (N), a remainder of iron (Fe), and other inevitable impurities, wherein a T value defined by Equation 1 below is 1380 or more and less than 1648;

hot-rolling the reheated steel slab to obtain a hot-rolled steel sheet;

coiling the hot-rolled steel sheet;

cold-rolling the coiled hot-rolled steel sheet to obtain a cold-rolled steel sheet;

heating the cold-rolled steel sheet to an annealing temperature of 800°C to 850°C, cooling the heated steel sheet to a cooling-end temperature of 450°C to 600°C, and then holding the steel sheet at a constant temperature for continuous annealing; and

cooling the continuously annealed steel sheet to room temperature, wherein an R value defined by Equation 4 below is 1,543 to 1,590.

[Equation 1]

$$T = 279 \times [C] + 711 \times [Mn] + 474 \times [Nb] + 177 \times [Ti] - 75 \times [Cr]$$

(wherein, in Equation 1, [C], [Mn], [Nb], [Ti], and [Cr] represent a content (wt%) of each element.)

$$R = 174 \times [C] + 680 \times [Mn] + 370 \times [Nb] + 177 \times [Ti] - 86 \times [Cr] + 0.33 \times [T1] - 0.05 \times [T2] \quad [Equation 4]$$

(wherein, in Equation 4, [C], [Mn], [Nb], [Ti], and [Cr] represent a content (wt%) of each element, and [T1] and [T2] respectively represent an annealing temperature (°C) and a cooling-end temperature (°C) in the continuous annealing step.)

7. The method of claim 6,

wherein in the reheating step, the steel slab has an RT value of 0.01 or more, as defined by Equation 2 below:

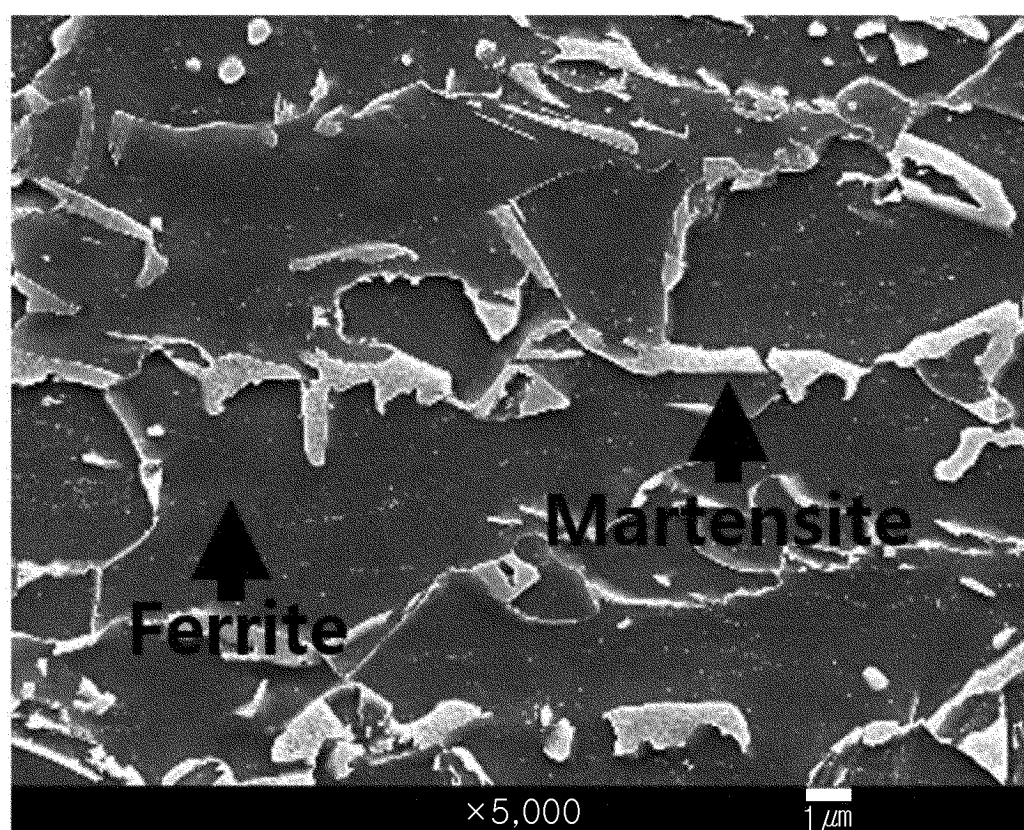
[Equation 2]

$$RT = [Si] + [Nb] + [Ti]$$

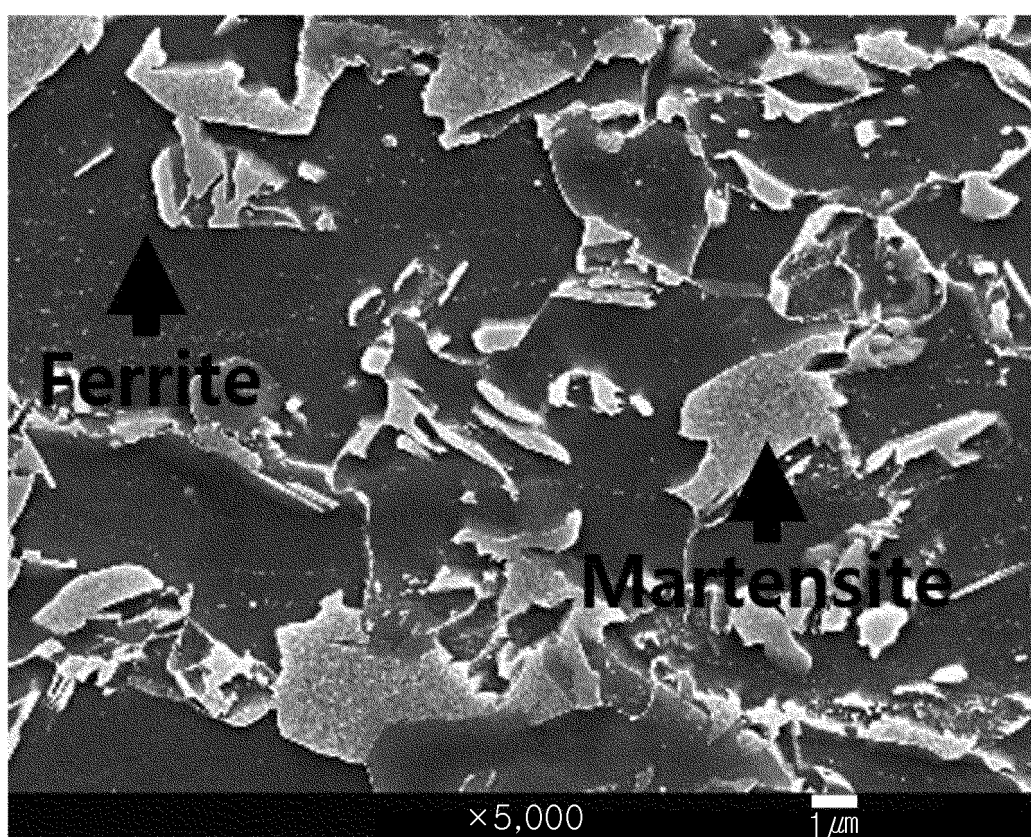
(wherein, in Equation 2, [Si], [Nb], and [Ti] represent a content (wt%) of each element.)

8. The method of claim 6,
wherein the reheating step is performed at 1,100°C to 1,300°C, and the step of obtaining the hot-rolled steel sheet is performed at a finish rolling temperature of 800°C to 950°C.
9. The method of claim 6,
wherein in the coiling step, the hot-rolled steel sheet is coiled at 400°C to 700°C and then cooled to room temperature at an average cooling rate of 0.1°C/s or less.
10. The method of claim 6,
wherein the step of obtaining the cold-rolled steel sheet is performed with a reduction ratio of 40% to 70%.
11. The method of claim 6,
wherein in the continuous annealing step, the steel sheet is cooled to the cooling-end temperature at an average cooling rate of 20°C/s or less.
12. The method of claim 6,
wherein in the continuous annealing step, the cold-rolled steel sheet is held at the cooling-end temperature for 50 seconds or more.
13. The method of claim 6,
further comprising, after the continuous annealing step, a step of galvanizing the continuously annealed steel sheet at 430°C to 490°C.
14. The method of claim 13,
further comprising, after the galvanizing step, a step of subjecting the galvanized steel sheet to an alloying heat treatment at 460°C to 530°C.

[Fig.1]



[Fig.2]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/096921

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; C22C 38/26(2006.01)i; C22C 38/28(2006.01)i; C22C 38/00(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 38/38(2006.01); C21D 8/02(2006.01); C21D 9/46(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/06(2006.01); C22C 38/58(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), 크롬(chromium), 니오븀(niobium), 티타늄(titanium), 규소(silicon), 페라이트(ferrite), 후레쉬 마르텐사이트(fresh martensite), 냉각(cooling), 소둔(annealing)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 6828855 B1 (JFE STEEL CORP.) 10 February 2021 (2021-02-10) See paragraphs [0052], [0072]-[0073], [0077], [0080]-[0082], [0089] and [0093], claims 1, 3-4 and 7-8 and table 3.	1-14
A	KR 10-2021-0080664 A (POSCO) 01 July 2021 (2021-07-01) See paragraphs [0182]-[0183] and claims 1-6.	1-14
A	US 2023-0349019 A1 (JFE STEEL CORPORATION) 02 November 2023 (2023-11-02) See paragraph [0088] and claim 15.	1-14
A	JP 2012-180569 A (KOBELITE LTD.) 20 September 2012 (2012-09-20) See paragraphs [0062]-[0064] and claims 1-2.	1-14
A	KR 10-2023-0094234 A (POSCO) 28 June 2023 (2023-06-28) See paragraphs [0192]-[0193] and claim 1.	1-14

☐ 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

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“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	Date of mailing of the international search report
18 March 2025	18 March 2025
Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208	
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/096921

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KR 10-2023-0094234 A	28 June 2023	None	

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REFERENCES CITED IN THE DESCRIPTION

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