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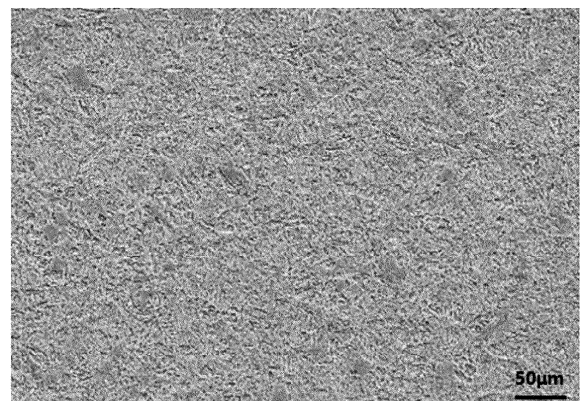
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- (71) Applicant: **POSCO Co., Ltd**  
**Gyeongsangbuk-do 37859 (KR)**

- (72) Inventors:  
• **KONG, Jong-Pan**  
**Gwangyang-si, Jeollanam-do 57807 (KR)**  
• **BANG, Chan-Woo**  
**Gwangyang-si, Jeollanam-do 57807 (KR)**  
• **HAN, Sang-Ho**  
**Gwangyang-si, Jeollanam-do 57807 (KR)**  
• **PARK, Man-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) The present invention relates to a cold-rolled steel sheet and a manufacturing method therefor and, more specifically, to a cold-rolled steel sheet suitable for use as a steel material for automotive reinforcements such as bumper beams, sill side beams, and the like, and for the protection of electric vehicle battery cases such as side frames, cross members, and the like, and to a manufacturing method therefor.

[Fig. 2]



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**Description**

## Technical Field

5 **[0001]** The present disclosure relates to a cold-rolled steel sheet and a manufacturing method thereof and, more specifically, to a cold-rolled steel sheet suitable for use as a steel material for automotive reinforcing members such as bumper beams, sill side beams, and the like, and for the protection of electric vehicle battery cases such as side frames, cross members, and the like, and to a manufacturing method thereof.

## 10 Background Art

**[0002]** Steel materials primarily used for reinforcing member components related to the crash safety of automobile passengers are required to have excellent workability characteristics, particularly excellent bendability, as well as ultra-high strength. To this end, research on ultra-high-strength steels having a tensile strength of 1470 MPa or more and using a single martensite phase, as well as methods for manufacturing the same, has been actively conducted.

15 **[0003]** Recently, a hot press forming (HPF) process has been developed in which a material is formed using a die at a high temperature, which is an environment favorable for forming, and then water-cooled to secure the required strength. Since the HPF process may secure high strength at the same thickness level, the HPF process has been widely used in the manufacture of components. However, the HPF process has disadvantages in that excessive equipment investment and increased process costs are required. Accordingly, there is a need to develop materials for cold stamping and roll forming. That is, there is a need to develop an ultra-high strength cold-rolled steel sheet which is suitable for use as a material for cold stamping and roll forming, has high strength and a high yield ratio to secure crash performance, and exhibits excellent bendability for component forming, spot weldability for component assembly, and corrosion resistance for extending component service life.

25 **[0004]** A representative example of the prior art of such a method is disclosed in Patent Document 1. Patent Document 1 relates to a steel containing C 0.25 to 0.4%, Si 1.0% or less, Mn 1.5 to 2.5%, P 0.02% or less, S 0.003% or less, Al 0.01 to 0.1%, N 0.005% or less, and B 0.0005 to 0.005%, and further containing Ti 0.005 to 0.1% and Nb 0.005 to 0.1% in a total amount of 0.005 to 0.1%, the steel having a single-phase martensitic structure, and discloses that the steel may be obtained by being heated and held in a temperature range of an Ae<sub>3</sub> transformation point or higher and 900°C or lower, rapidly cooling the steel to 200°C or lower at an average cooling rate of 300°C/s, and subsequently tempering the steel at 250°C or lower. However, in Patent Document 1, there is a problem in that rapid cooling (water cooling) causes inferior shape characteristics (flatness), thereby causing defects during forming.

30 **[0005]** Patent Document 2 relates to a thin steel sheet containing C 0.05% or more and 0.35% or less, Si 0.01% or more and 2.0% or less, Mn 0.8% or more and 3.0% or less, P 0.05% or less, S 0.005% or less, Al 0.005% or more and 0.10% or less, and N 0.0060% or less, and having a steel microstructure in which a ferrite area fraction is 0% or more and 90% or less, a bainite area fraction is 5% or less (including 0%), a martensite and tempered martensite area fraction is 10% or more (including 100%), and a retained austenite area fraction is 2.0% or less (including 0%), and a standard deviation of yield strength in a width direction is 30 MPa or less, and a maximum bending amount of the steel sheet when sheared at a length of 1 m is 10 mm or less. However, in Patent Document 2, there is a problem in that shape defects occur due to rapid cooling after annealing.

40 **[0006]** To solve the above-described problems, there is a need to develop an ultra-high strength cold-rolled steel sheet having a tensile strength of 1470 MPa or more while having an excellent shape, a low yield ratio (YR), and excellent bendability and hole expansion ratio.

45 [Related Art Document]

[Patent Document]

50 **[0007]**

(Patent Document 1) Japanese Patent Laid-Open Publication No. 2010-248565

(Patent Document 2) Japanese Patent Laid-Open Publication No. 2020-019992

## 55 Summary of Invention

## Technical Problem

**[0008]** An aspect of the present disclosure is to provide a cold-rolled steel sheet and a manufacturing method

thereof.

# Solution to Problem

5 **[0009]** According to an aspect of the present disclosure, a cold-rolled steel sheet includes by wt%, carbon (C): 0.180 to 0.280%, silicon (Si): 0.030 to 0.70%, manganese (Mn): 1.50 to 2.40%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, boron (B): 0.00050 to 0.0050%, phosphorus (P): 0.030% or less (excluding 0%), sulfur (S): 0.00350% or less (excluding 0%), nitrogen (N): 0.010% or less (excluding 0%), aluminum (Al): 0.010 to 0.10%, niobium (Nb): 0.0030 to 0.050%, and titanium (Ti): 0.0050 to 0.050%, and the balance being Fe and unavoidable  
10 impurities, and satisfying Relational Equations 1 to 3 below, the cold-rolled steel sheet comprising: a central portion; and a surface layer portion formed on an outer side of the central portion in a thickness direction, in which a residual stress of the surface layer portion is -30 MPa or less, and a surface roughness (Rsk) of the surface layer portion is -0.7 or more.

15  $0.31 \leq X = C + Mn/20 + Si/30 + 2P + 4S \leq 0.40$  [Relational Expression 1]

$100 \leq Y = 48.8 + 49\log C + 35.1Mn + 25.9Si + 14.5Ni + 9.6Cu + 76.5Cr + 105.9Mo + 1325Nb + 10000B \leq 195$  [Relational Expression 2]

20

[Relational Equation 3]  $270 \leq Y/X \leq 600$

(However, the content of each alloying element in Relational Equations 1 to 3 above is in wt%.)

25 **[0010]** The surface layer portion may be a region extending from a surface of a steel material to 20  $\mu\text{m}$  in a thickness direction.

**[0011]** The microstructure of the central portion may include, in area %, a total of 5% or less (including 0%) of one or more of ferrite and bainite, and the balance being one or more of martensite and tempered martensite.

30 **[0012]** The microstructure of the surface layer portion may include, in area %, a total of 10% or less (excluding 0%) of one or more of ferrite and bainite, and the balance being one or more of martensite and tempered martensite.

**[0013]** In the cold-rolled steel sheet of the present disclosure, upon measuring EBSD, when a number fraction of a region having a KAM value of 0 to 5.0° may be set to 100%, a number fraction of a region having a KAM value of 0 to 1.0° at a 1/4 position in the thickness direction may be set to 22 to 30%.

**[0014]** The cold-rolled steel sheet may have a product of Rsk and Pc of -130 or greater.

35 **[0015]** The cold-rolled steel sheet may have a yield strength (YS) of 1000 to 1300 MPa, a tensile strength (TS) of 1470 to 1670 MPa, a yield ratio (YS/TS) of 0.85 or less, and an elongation (El) of 4 to 10%.

**[0016]** The cold-rolled steel sheet may have a yield strength (YS)  $\times$  elongation (El) of 4000 MPa% or more.

**[0017]** The cold-rolled steel sheet may have a bendability (R/t) of 3.5 or less.

**[0018]** The cold-rolled steel sheet may have a hole expansion ratio (HER) of 30% or more.

40 **[0019]** The cold-rolled steel sheet may have a hardness deviation of 250 Hv or less at a 1/4 position in the thickness direction.

**[0020]** The cold-rolled steel sheet may have a coating layer formed on at least one surface.

45 **[0021]** According to another aspect of the present disclosure, a manufacturing method of a cold-rolled steel sheet includes heating a slab comprising, by wt%, carbon (C): 0.180 to 0.280%, silicon (Si): 0.030 to 0.70%, manganese (Mn): 1.50 to 2.40%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, boron (B): 0.00050 to 0.0050%, phosphorus (P) 0.030% or less (excluding 0%), sulfur (S): 0.00350% or less (excluding 0%), nitrogen (N): 0.010% or less (excluding 0%), aluminum (Al): 0.010 to 0.10%, niobium (Nb): 0.0030 to 0.050%, and titanium (Ti): 0.0050 to 0.050%, and the balance being Fe and unavoidable impurities, and satisfying Relational Equations 1 to 3 below; obtaining a hot-rolled steel sheet by finish hot rolling the heated slab; coiling the hot-rolled steel sheet; cold  
50 rolling the coiled hot-rolled steel sheet using a roll having a surface roughness (Ra) of 2.5  $\mu\text{m}$  or more to obtain the cold-rolled steel sheet; continuously annealing the cold-rolled steel sheet; primarily cooling the continuously annealed cold-rolled steel sheet; secondarily cooling the primarily cooled cold-rolled steel sheet; reheating the secondarily cooled cold-rolled steel sheet and then overaging-treating the cold-rolled steel sheet; temper-rolling the overaging-treated cold-rolled steel sheet with a rolling force of 500 to 1000 tons; and tension-leveling the temper-rolled cold-  
55 rolled steel sheet with an elongation of 0.030 to 0.50%.

$0.31 \leq X = C + Mn/20 + Si/30 + 2P + 4S \leq 0.40$  [Relational Expression 1]

$$100 \leq Y = 48.8 + 49\log C + 35.1Mn + 25.9Si + 14.5Ni + 9.6Cu + 76.5Cr + 105.9Mo + 1325Nb + 10000B \leq 200 \quad [\text{Relational Expression 2}]$$

$$[\text{Relational Equation 3}] \quad 270 \leq Y/X \leq 600$$

(However, the content of each alloying element in Relational Equations 1 to 3 above is in wt%.)

**[0022]** The heating of the slab may be performed at 1100 to 1300°C.

**[0023]** The finish hot rolling may be performed at Ar3 to Ar3+120°C.

**[0024]** The coiling may be performed at Ms to 600°C.

**[0025]** The cold rolling may be performed with a cold reduction ratio of 45 to 70%.

**[0026]** The continuous annealing may be performed at Ac3+20°C to Ac3+80°C.

**[0027]** The continuous annealing may be performed for 30 to 230 seconds.

**[0028]** During the primary cooling, a primary cooling end temperature may be controlled to 670 to 750°C and the primary cooling is performed at an average cooling rate of 1 to 6°C/s.

**[0029]** During the secondary cooling, the secondary cooling end temperature Tf may be controlled to 110 to 300°C and the secondary cooling is performed at an average cooling rate of 30 to 300°C/s.

**[0030]** During the secondary cooling, Mf-secondary cooling end temperature Tf may be controlled to be 130°C or lower.

**[0031]** During the overaging treatment, an overaging treatment temperature (H) may be controlled to 100 to 250°C and the overaging treatment may be performed for 5 to 12 minutes.

**[0032]** During the overaging treatment, the overaging treatment temperature H - secondary cooling end temperature Tf may be controlled to be 100°C or lower.

**[0033]** The manufacturing method of a cold-rolled steel sheet may further include, after the tension leveling, forming a coating layer on at least one surface of the cold-rolled steel sheet.

#### Advantageous Effects of Invention

**[0034]** According to an aspect of the present disclosure, it is possible to provide a cold-rolled steel sheet and a manufacturing method thereof.

#### Brief Description of Drawings

**[0035]**

FIG. 1 is an example of an image of a steel sheet to which an ultrafine hardness tester is applied to measure hardness deviation according to an example embodiment of the present disclosure.

FIG. 2 is an image of Invention Example 1 according to an example embodiment of the present disclosure observed using a scanning electron microscope (SEM).

FIG. 3 is an image of Comparative Example 9 according to an example embodiment of the present disclosure observed using the scanning electron microscope (SEM).

#### Best Mode for Invention

**[0036]** Terminologies used herein are to mention only a specific exemplary embodiment, and are not to limit the present disclosure. Singular forms used herein include plural forms as long as phrases do not clearly indicate an opposite meaning. A term "including" used in the present specification concretely indicates specific properties, regions, integer numbers, steps, operations, elements, and/or components, and is not to exclude presence or addition of other specific properties, regions, integer numbers, steps, operations, elements, components, and/or a group thereof.

**[0037]** All terms including technical terms and scientific terms used herein have the same meaning as the meaning generally understood by those skilled in the art to which the present disclosure pertains unless defined otherwise. Terms defined in commonly used dictionaries are additionally interpreted as having meanings consistent with related technical literature and currently disclosed content, and are not interpreted in ideal or very formal meanings unless defined.

**[0038]** Hereinafter, a cold-rolled steel sheet according to an embodiment of the present disclosure will be described. First, the alloy composition of the present disclosure will be described. The alloy composition described below refers to wt% unless otherwise specified.

Carbon (C): 0.180 to 0.280%

**[0039]** C is an interstitial solid solution element and is the most effective and important element for improving the strength of steel. In addition, C is an element that should be added to secure the strength of martensitic steel. When the C content is less than 0.180%, it may be difficult to obtain the yield ratio and tensile strength targeted in the present disclosure. When the C content exceeds 0.280%, the strength increases rapidly, resulting in the deterioration in elongation. Additionally, weldability may be inferior. Therefore, the C content preferably ranges from 0.180 to 0.280%. A lower limit of the C content is more preferably 0.190%, and even more preferably 0.20%. The upper limit of the C content is more preferably 0.270%.

Silicon (Si): 0.030 to 0.70%

**[0040]** Si is an element effective in increasing resistance to tempering softening, and is also an element effective in improving strength through solid solution strengthening. When the Si content is less than 0.030%, it may be difficult to sufficiently obtain the above-described effects. When the Si content exceeds 0.70%, there is a risk that excessive ferrite will be generated after continuous annealing and cooling, thereby weakening the strength of steel. Furthermore, as the Si is an element that increases resistivity, resistance spot weldability may be inferior. Therefore, the Si content preferably ranges from 0.030 to 0.70%. The lower limit of the Si content is more preferably 0.050%. The upper limit of the Si content is more preferably 0.60%.

Manganese (Mn): 1.50 to 2.40%

**[0041]** Mn is an element added to ensure strength. When the Mn content is less than 1.50%, as the hardenability is low, when the cooling rate is not sufficiently fast during cooling after continuous annealing, martensite is not formed, making it difficult to secure the level of strength targeted in the present disclosure. When the Mn content exceeds 2.40%, the Ms temperature decreases during cooling after continuous annealing, and as the temperature at which cooling should end decreases, the shape of the steel sheet becomes poor. Furthermore, it is difficult to secure the martensite structure. In addition, during steelmaking/continuous casting operations, Mn-based segregation zones occur along the longitudinal direction of the slab, resulting in the deterioration in bendability. In other words, as the Mn is segregated in the thickness direction and forms manganese bands (Mn bands) within the slab, there is a problem in that cracks occur during continuous casting and defects occur more frequently during the rolling process. Therefore, the Mn content preferably ranges from 1.50 to 2.40%. The lower limit of the Mn content is more preferably 1.60%. The upper limit of the Mn content is more preferably 2.30%.

Chromium (Cr): 0.0050 to 0.60%

**[0042]** Cr is an element that facilitates securing a low-temperature transformation structure by suppressing ferrite transformation. In addition, when utilizing a continuous annealing process involving slow cooling as in the present disclosure, there is an advantage in suppressing ferrite formation. When the Cr content is less than 0.0050%, as the hardenability is low, when the cooling rate is not sufficiently fast during cooling after continuous annealing, martensite is not formed, making it difficult to secure the level of strength targeted in the present disclosure. When the Cr content exceeds 0.60%, delayed fracture resistance may deteriorate, carbides such as CrC may be formed, thereby reducing bendability, and manufacturing costs may increase due to an excessive alloy addition. Therefore, the Cr content preferably ranges from 0.0050 to 0.60%. The lower limit of the Cr content is more preferably 0.010%. The upper limit of the Cr content is more preferably 0.50%.

Molybdenum (Mo): 0.0030 to 0.50%

**[0043]** Mo is an element that exhibits effects such as improving hardenability of steel, generating Mo-based fine carbides that serve as hydrogen trap sites, and improving the delayed fracture resistance through martensite refinement. When the Mo content is less than 0.0030%, it may be difficult to sufficiently obtain the above-described effects. When the Mo content exceeds 0.50%, the above-described effects are not significantly increased compared to the increase in manufacturing costs caused by the addition of expensive alloying elements. Therefore, the Mo content preferably ranges from 0.0030 to 0.50%. The lower limit of the Mo content is more preferably 0.0050%. The upper limit of the Mo content is more preferably 0.40%.

Boron (B): 0.00050 to 0.0050%

**[0044]** B is an element that inhibits ferrite formation, and as a result, the present disclosure has the advantage of inhibiting the formation of ferrite during cooling after continuous annealing. When the B content is less than 0.00050%, there is no hardenability effect at all, so that not only may the strength targeted by the present disclosure not be secured, but also excessive ferrite may be formed in the surface layer portion, thereby deteriorating bendability. When the B content exceeds 0.0050%, the ductility may be significantly reduced. Therefore, the B content preferably ranges from 0.00050 to 0.0050%. The lower limit of the B content is more preferably 0.00070%. The upper limit of the B content is more preferably 0.0040%.

Phosphorus (P): 0.030% or less (excluding 0%)

**[0045]** P is an impurity element contained in steel. When the P content exceeds 0.030%, weldability deteriorates, and there is a risk of brittleness occurring in the steel. Meanwhile, although it is advantageous that the P is not included in the steel as much as possible, 0% is excluded in consideration of cases where P is unavoidably included during the manufacturing process. Therefore, the P content is preferably 0.030% or less (excluding 0%). The P content is more preferably 0.0250% or less.

Sulfur (S): 0.00350% or less (excluding 0%)

**[0046]** Similar to P, S is an impurity element contained in steel. When the S content exceeds 0.00350%, the ductility and weldability may be impaired, and a large amount of MnS precipitates may be formed, leading to inferior bendability. Meanwhile, although it is advantageous that the S is not included in the steel as much as possible, 0% is excluded in consideration of cases where P is unavoidably included during the manufacturing process. Therefore, the S content is preferably 0.00350% or less (excluding 0%). The upper limit of the S content is more preferably 0.0030%, and even more preferably 0.0020%.

Nitrogen (N): 0.010% or less (excluding 0%)

**[0047]** N is an impurity element, and when the N content exceeds 0.010%, it significantly increases the risk of cracking during continuous casting due to the formation of AlN, etc. Although it is advantageous that the N content is not included in the steel as much as possible, 0% is excluded in consideration of cases where P is unavoidably included during the manufacturing process. Therefore, the N content is preferably in the range of 0.010% or less (excluding 0%). The N content is more preferably 0.0080% or less, and even more preferably 0.0060% or less.

Aluminum (Al): 0.010 to 0.10%

**[0048]** Al may be added to remove oxygen from molten steel. When the Al content is less than 0.010%, deoxidation is not sufficiently achieved, which impairs the cleanliness of the steel material. When the Al content exceeds 0.10%, not only does the castability of the slab deteriorate, but the temperature required for single-phase heating during continuous annealing also increases, which may lead to production and equipment problems. Therefore, the Al content preferably ranges from 0.010 to 0.10%. The upper limit of the Al content is more preferably 0.0750%.

Niobium (Nb): 0.0030 to 0.050%

**[0049]** Nb is an element that segregates at the austenite grain boundaries, suppresses the coarsening of austenite grains during the continuous annealing process, and contributes to the strength improvement by forming fine precipitates. When the Nb content is less than 0.0030%, sufficient austenite grain refinement and precipitation strengthening effects may not be obtained. When the Nb content exceeds 0.050%, the precipitation of coarse carbonitrides increases, and there is a risk that the strength and elongation may decrease due to the reduction in carbon content in the steel. In addition, there are problems such as reduced workability of a base material and increased manufacturing costs. Therefore, the Nb content preferably ranges from 0.0030 to 0.050%. The lower limit of the Nb content is more preferably 0.0040%. The upper limit of the Nb content is more preferably 0.040%.

Titanium (Ti): 0.0050 to 0.050%

**[0050]** Ti is a nitride-forming element that scavenges solute N by precipitating it as TiN. When the Ti content is less than 0.0050%, not only is it difficult to obtain a strength-increasing effect, but also the effect of scavenging solute N is

reduced, thereby forming a large amount of AlN and causing cracks during the continuous casting. When the Ti content exceeds 0.050%, the strength of martensite may decrease due to precipitation of additional carbides in addition to the removal of solute N, and hole expansion ratio and bendability may be deteriorated due to excessive formation of carbonitrides such as TiC and TiN. Therefore, the Ti content preferably ranges from 0.0050 to 0.050%. The lower limit of the Ti content is more preferably 0.010%. The upper limit of the Ti content is more preferably 0.040%.

**[0051]** The remaining component is iron (Fe). However, since the unintended impurities from raw materials or the surrounding environment may inevitably be mixed in a normal manufacturing process, the unintended impurities may not be excluded. Since these impurities are known to those skilled in the ordinary manufacturing process, not all of them are specifically mentioned in this specification.

**[0052]** It is preferable that the cold-rolled steel sheet of the present disclosure satisfies the above-described alloy composition and simultaneously satisfies Relational Equations 1 to 3 below.

$$0.310 \leq X = C + Mn/20 + Si/30 + 2P + 4S \leq 0.40$$

[Relational Expression 1]

**[0053]** The above Relational Equation 1 is a component relational equation closely related to weld hardness. When the X value is less than 0.310, it is difficult to sufficiently secure the weld hardness and strength. When the X value exceeds 0.40, the weld hardness becomes excessively high, increasing the risk of brittle fracture, which may lead to a decline in impact stability. Therefore, the X value preferably ranges from 0.310 to 0.40. The lower limit of the X value is more preferably 0.320. The upper limit of the X value is more preferably 0.390.

$$100 \leq Y = 48.8 + 49\log C + 35.1Mn + 25.9Si + 14.5Ni + 9.6Cu + 76.5Cr + 105.9Mo + 1325Nb + 10000B \leq 190$$

[Relational Expression 2]

**[0054]** The above Relational Equation 2 is a component relational equation related to hardenability for securing the microstructure and strength targeted by the present disclosure. When a Y value is less than 100, the hardenability is insufficient, making it difficult to obtain the microstructure targeted by the present disclosure and thus difficult to secure sufficient strength. When the Y value exceeds 195, not only do the manufacturing costs increase, but the strength becomes excessively high, leading to a problem of reduced elongation. Therefore, the Y value preferably ranges from 100 to 195. The lower limit of the Y value is more preferably 105. The upper limit of the Y value is more preferably 190.

$$[Relational Equation 3] \quad 270 \leq Y/X \leq 600$$

**[0055]** The above Relational Equation 3 is a component relational equation for securing an appropriate level of weld hardness and hardenability. When the Y/X value is less than 270, Ceq is satisfied, but due to the insufficient hardenability, it may be difficult to obtain the target microstructure and thus difficult to secure strength. When the Y/X value exceeds 600, sufficient hardenability is secured, but the low Ceq may make it difficult to secure weld strength. Therefore, the Y/X value preferably ranges from 270 to 600. The lower limit of the Y/X value is more preferably 310. The upper limit of the Y/X value is more preferably 580.

**[0056]** Meanwhile, the cold-rolled steel sheet of the present disclosure may be divided, in terms of microstructure, into a central portion and a surface layer portion formed on an outer side of the central portion in a thickness direction. Meanwhile, since the depth of the surface layer portion may change depending on the thickness of the steel sheet, it is not specifically limited thereto, but as an example, the surface layer portion may be an area up to 20  $\mu\text{m}$  in the thickness direction from the surface of the steel sheet.

**[0057]** The microstructure of the central portion may include, in area %, a total of one or more types of ferrite and bainite: 5% or less (including 0%), and the balance being one or more types of martensite and tempered martensite, and the microstructure of the surface layer portion may include, in area %, a total of one or more types of ferrite and bainite: 10% or less (excluding 0%), and the balance being one or more types of martensite and tempered martensite.

**[0058]** It is preferable that the main phase of the microstructure of the central portion includes one or more types of martensite and tempered martensite. The martensite and tempered martensite are structures that are highly advantageous for securing the strength, hole expansion hole, bending properties, and weldability targeted by the present disclosure. However, due to the manufacturing process, one or more types of ferrite and bainite may inevitably be formed, and when the total fraction of one or more types of ferrite and bainite exceeds 5%, it may be difficult to secure the physical properties to be obtained by the present disclosure. Therefore, the total fraction of one or more types of ferrite and bainite is preferable 5% or less, and more preferably 3% or less.

**[0059]** It is preferable that the main phase of the microstructure of the surface layer portion includes one or more types of martensite and tempered martensite. Furthermore, it is preferable that the total fraction of one or more types

of ferrite and bainite be 10% or less (excluding 0%). Since the ferrite and bainite are softer than the martensite and tempered martensite, the bending properties may be further improved by forming an appropriate amount of ferrite and bainite in the surface layer portion. When the total fraction of one or more of the ferrite and bainite exceeds 10%, it is difficult to secure the sufficient strength, and the bending properties may deteriorate. Therefore, the total fraction of one or more types of ferrite and bainite is preferable 10% or less, and more preferably 7% or less. In the present disclosure, the lower limit of the total fraction of one or more of the ferrite and bainite is not specifically limited, but as an example, may be 1%.

**[0060]** In the cold-rolled steel sheet of the present disclosure, upon measuring EBSD, when a number fraction of a region having a KAM value of 0 to 5.0° may be set to 100%, a number fraction of a region having a KAM value of 0 to 1.0° at a 1/4 position in the thickness direction may be set to 22 to 30%. The dislocation density within grains may be evaluated by a kernel average misorientation (KAM) value. The KAM value is an average value of the amount of crystal rotation (crystal orientation difference) between the target measurement point and the surrounding measurement points, and the larger this value, the more deformation exists within the crystal. The inventors investigated the relationship between the KAM value and the microstructure and confirmed that differences in material properties occur depending on the number fraction of the region where the KAM value is 0 to 1.0° at the 1/4 position in the thickness direction. In the present disclosure, in order to secure the target physical properties, it is preferable to control the number fraction of a region having a KAM value of 0 to 1.0° at a 1/4 position in the thickness direction to 22 to 30%. When the number fraction is less than 22%, a large fraction of highly deformed structures is included, which may make it difficult to secure the target yield strength, and when the number fraction exceeds 30%, a large fraction of less deformed structures is included, which may make it difficult to secure the target tensile strength. Therefore, it is preferable for the number fraction in the region where the KAM value at the 1/4 position in the thickness direction is 0 to 1.0° to have a range of 22 to 30%. The lower limit of the number fraction is more preferably 23% and the upper limit of the number fraction is more preferably 29%. Meanwhile, in the present disclosure, since the region outside the range where the KAM value is 0 to 5.0°, that is, the region exceeding 5.0° has almost no effect on the characteristics of the present disclosure, it is preferable to control the number fraction in the region where the KAM value is 0 to 1.0° by considering the number fraction in the region where the KAM value is 0 to 5.0° as 100%.

**[0061]** In the cold-rolled steel sheet of the present disclosure, the residual stress of the surface layer portion is preferably -30 MPa or less. As the residual stress MPa of the surface layer portion approaches zero or becomes + value, the tensile stress is applied, which may be disadvantageous for securing bending properties and hydrogen embrittlement resistance. That is, in the present disclosure, the bending properties and hydrogen embrittlement resistance may be improved by controlling the residual stress of the surface layer portion to a level of -30 MPa or less. Therefore, the residual stress of the surface layer portion is preferably -30 MPa or less, and more preferably -50 MPa or less. Meanwhile, in the present disclosure, since it is advantageous for the residual stress of the surface layer portion to be lower, there is no specific limitation on the lower limit thereof. However, as an example, the lower limit of the residual stress of the surface layer portion may be -300 MPa.

**[0062]** In the cold-rolled steel sheet of the present disclosure, the surface roughness Rsk is preferably -0.7 or higher. The surface roughness Rsk (skewness) is one of several factors of surface roughness related to the asymmetry of sharp protrusions. The closer the value of the surface roughness Rsk is to 0 or the more positive the value is, the more advantageous it is for securing bending properties. As the surface roughness Rsk becomes more negative, valleys on the flat surface become deeper, causing stress concentration in these regions and increasing sensitivity to crack formation, thereby deteriorating bending properties. When the value of the surface roughness Rsk is less than -0.7, the bending properties may deteriorate. Therefore, the surface roughness Rsk preferably has a range of -0.7 or greater. The surface roughness Rsk is more preferably -0.65 or greater, and even more preferably -0.6 or greater. Meanwhile, in the present disclosure, a higher surface roughness Rsk is more advantageous, and thus the upper limit thereof is not particularly limited. However, as an example, the upper limit of the surface roughness Rsk may be +0.5.

**[0063]** The cold-rolled steel sheet of the present disclosure may have a product of Rsk and Pc of -130 or greater. The Pc is a factor representing the number of peaks that completely deviate from the bandwidth within a unit length. The closer the product of Rsk and Pc is to 0, or the more positive the value thereof, the more favorable the bending properties become. That is, in the present disclosure, the bending properties may be improved by controlling the product of Rsk and Pc to a level of -130 or greater. Therefore, the product of Rsk and Pc is preferably -130 or greater, and more preferably -120 or greater. Meanwhile, in the present disclosure, since a higher product of Rsk and Pc is advantageous, there is no specific limitation on its upper limit. However, as an example, the upper limit of the product of Rsk and Pc may be +60.

**[0064]** As described above, the cold-rolled steel sheet of the present disclosure may have a yield strength of 1,000 to 1,300 MPa, a tensile strength of 1,470 to 1,670 MPa, a yield ratio of 0.85 or less, an elongation of 4 to 10%, a bendability (R/t) of 3.5 or less, and a hole expansion ratio (HER) of 30% or more. The yield ratio is more preferably 0.80 or less, and since the lower yield ratio is advantageous in the present disclosure, the lower limit thereof is not specifically limited; however, as an example, the lower limit of the yield ratio may be 0.7. The bendability is more

preferably 3.0 or less, and in the present disclosure, a lower bendability is more advantageous. Accordingly, the lower limit thereof is not particularly limited, but, as an example, the lower limit of the bendability may be 2.5. The hole expansion ratio is more preferably 35% or more, and since the higher hole expansion ratio is advantageous in the present disclosure, the upper limit thereof is not specifically limited, but as an example, the upper limit of the hole expansion ratio may be 20%. In addition, the cold-rolled steel sheet of the present disclosure may have a yield strength  $YS \times$  elongation  $EI$  of 4000 MPa% or more.

**[0065]** The cold-rolled steel sheet of the present disclosure may have a hardness deviation of 250 Hv or less at a 1/4 position in the thickness direction. By controlling the hardness deviation to a low level in this way, the excellent hole expansion ratio may be secured. The hardness deviation may more advantageously be 240 Hv or less; since the lower hardness deviation is more advantageous in the present disclosure, the lower limit thereof is not specifically limited, but as an example, the lower limit of the hardness deviation may be 230 Hv.

**[0066]** The thickness of the cold-rolled steel sheet of the present disclosure may be 0.6 to 2.3 mm. The lower limit of the thickness of the cold-rolled steel sheet is more preferably 0.7 mm, and more preferably 0.8 mm. The upper limit of the thickness of the cold-rolled steel sheet is more preferably 2.2 mm, and even more preferably 2.1 mm.

**[0067]** The cold-rolled steel sheet of the present disclosure may have a coating layer formed on at least one surface. In the present disclosure, the type of coating layer is not specifically limited, and any type of coating layer commonly used in the relevant technical field may be formed. However, as an example, the coating layer may be an electro-galvanized layer.

**[0068]** Hereinafter, a manufacturing method of a cold-rolled steel sheet according to an example embodiment of the present disclosure will be described.

**[0069]** First, a slab satisfying the above-described alloy composition and Relational Equations 1 to 3 is heated. The slab heating process is performed to facilitate the subsequent hot rolling process and to sufficiently obtain the physical properties of the target steel sheet. The heating of the slab may be performed at 1100 to 1300°C. When the slab heating temperature is below 1100°C, a problem arises in which the hot rolling load increases rapidly. When the slab heating temperature exceeds 1300°C, the amount of surface scale increases, and the yield of the material decreases. The lower limit of the slab heating temperature is more preferably 1110°C, more preferably 1120°C, and most preferably 1130°C. The upper limit of the slab heating temperature is more preferably 1290°C, even more preferably 1280°C, and most preferably 1270°C.

**[0070]** Subsequently, the heated slab is finished hot-rolled to obtain a hot-rolled steel sheet. The finish hot rolling may be performed at  $Ar3$  to  $Ar3+4+120^\circ C$ . When the finish hot-rolling temperature is lower than  $Ar3$ , rolling is performed in a ferrite+austenite intercritical region or a ferrite region, thereby forming a mixed grain structure, and sheet breakage may occur due to fluctuations in hot-rolling load. When the finish hot-rolling temperature exceeds  $Ar3+120^\circ C$ , a large amount of surface scale may be generated, and the surface quality may deteriorate. The lower limit of the finish hot-rolling temperature is more preferably  $Ar3+10^\circ C$ , more preferably  $Ar3+420^\circ C$ , and most preferably  $Ar3+30^\circ C$ . The upper limit of the finish hot-rolling temperature is more preferably  $Ar3+110^\circ C$ , more preferably  $Ar3+100^\circ C$ , and most preferably  $Ar3+90^\circ C$ . Meanwhile,  $Ar3$  refers to the temperature at which austenite begins to transform into ferrite upon cooling, and may be calculated using the following Equation 1.

$$[Equation\ 1] \quad Ar3(^{\circ}C) = 910 - 203\sqrt{C} + 44.7Si + 31.5Mo$$

**[0071]** Thereafter, the hot-rolled steel sheet is coiled. The coiling may be performed at  $Ms$  to 600°C. When the coiling temperature exceeds 600°C, internal oxidation occurs on the surface of the steel sheet, causing the microstructure formed in the surface layer portion to become non-uniform, so the bending properties may deteriorate. Meanwhile, it is preferable to control the coiling temperature to be low in order to secure material uniformity in the longitudinal and widthwise directions by forming the microstructure of the hot-rolled steel sheet as a single-phase structure rather than a complex structure as much as possible. However, when the coiling temperature is lower than  $Mf$ , the strength of the hot-rolled steel sheet becomes excessively high, thereby increasing the rolling load during a subsequent cold-rolling process, which may make actual production impossible. The lower limit of the coiling temperature is more preferably  $Ms+50^\circ C$ . The upper limit of the coiling temperature is more preferably 550°C. The  $Ms$  refers to a temperature at which austenite begins to transform into martensite upon cooling, and may be calculated using Equation 2 below.

$$Ms(^{\circ}C) = 539 - 423C - 30.4Mn - 7.5Si + 30Al - 17.7Ni - 12.1Cr - 7.5Mo \quad [Equation\ 2]$$

**[0072]** Meanwhile, after the coiling, it may be cooled by air cooling or water cooling. In addition, after the cooling, a pickling process may be performed to remove the oxide layer formed on the surface of the hot-rolled steel sheet.

**[0073]** Thereafter, the coiled hot-rolled steel sheet is cold-rolled by a roll having a surface roughness ( $Ra$ ) of 2.5  $\mu m$

or more to obtain the cold-rolled steel sheet. When the surface roughness  $R_a$  of the cold-rolling roll is less than 2.5  $\mu\text{m}$ , the negative value of the surface roughness  $R_{sk}$  of the steel sheet becomes excessively large, which may degrade the bending properties. In the present disclosure, the upper limit is not specifically limited because the larger the surface roughness  $R_a$  of the cold-rolling roll, the fewer deep grooves are formed in the rolling direction that are inferior to the bending properties. The surface roughness  $R_a$  of the cold-rolling roll may preferably be 3.0  $\mu\text{m}$  or more, and since a larger surface roughness  $R_a$  of the cold-rolling roll is more advantageous in the present disclosure, the upper limit thereof is not particularly limited. As an example, the upper limit of the surface roughness ( $R_a$ ) of the cold-rolling roll may be 6.5  $\mu\text{m}$ . The cold rolling may be performed with a cold reduction ratio of 45 to 70%. When the cold reduction ratio is less than 45%, not only is it difficult to secure the thickness desired in the present disclosure, but there is also a risk that the residual crystal grains formed during hot rolling may cause austenite to form during annealing heat treatment, thereby affecting the final physical properties. Furthermore, the negative value of the surface roughness  $R_{sk}$  may become excessively large, potentially leading to inferior bending properties. When the cold reduction ratio exceeds 70%, the amount of reduction in the length and width directions may become uneven due to work hardening occurring during the cold rolling, which may result in material variation of the steel sheet. Additionally, it may be difficult to secure the thickness desired in the present disclosure due to the rolling load. Therefore, it is preferable for the cold reduction ratio to have a range of 45 to 70%. The lower limit of the cold reduction ratio is more preferably 46%, more preferably 47%, and most preferably 48%. The upper limit of the cold reduction ratio is more preferably 68%, even more preferably 66%, and most preferably 64%.

**[0074]** Subsequently, the cold-rolled steel sheet is continuously annealed. The continuous annealing may be performed at  $\text{Ac}3+20^\circ\text{C}$  to  $\text{Ac}3+80^\circ\text{C}$ . When the continuous annealing temperature is lower than  $\text{Ac}3+20^\circ\text{C}$ , intercritical annealing rather than annealing in a single-phase region occurs over the entire length of the steel sheet, thereby forming a mixed grain structure. As a result, it may be difficult to secure the physical properties targeted by the present disclosure, and in particular, the hardness difference between phases becomes large, which may significantly deteriorate hole expansion ratio. When the continuous annealing temperature exceeds  $\text{Ac}3+80^\circ\text{C}$ , equipment trouble may occur due to overloading of the annealing furnace. The lower limit of the continuous annealing temperature is more preferably  $\text{Ac}3+21^\circ\text{C}$ , even more preferably  $\text{Ac}3+24^\circ\text{C}$ , and most preferably  $\text{Ac}3+25^\circ\text{C}$ . The upper limit of the continuous annealing temperature is more preferably  $\text{Ac}3+70^\circ\text{C}$ , even more preferably  $\text{Ac}3+60^\circ\text{C}$ , and most preferably  $\text{Ac}3+50^\circ\text{C}$ . Meanwhile, the  $\text{Ac}3$  refers to the temperature at which austenite begins to appear upon heating and may be calculated using Equation 3 below.

$$\text{Ac}3(^{\circ}\text{C}) = 875 - 206\text{C} + 26.2\text{Si} - 25.0\text{Mn} - 12.3\text{Cr} + 9.12\text{Mo} + 50.2\text{Nb} + 148\text{Ti} - 131\text{B} \quad [\text{Equation 3}]$$

**[0075]** The continuous annealing may be performed for 30 to 230 seconds. When the continuous annealing time is less than 30 seconds, there is a disadvantage in that it is difficult to secure a single-phase austenite structure. When the continuous annealing time exceeds 230 seconds, the austenite size becomes coarsened, which has a disadvantage in that it is difficult to secure strength and bending properties. The lower limit of the continuous annealing time is more preferably 40 seconds, even more preferably 50 seconds, and most preferably 60 seconds. The upper limit of the continuous annealing time is more preferably 220 seconds, even more preferably 210 seconds, and most preferably 200 seconds.

**[0076]** Thereafter, the continuously annealed cold-rolled steel sheet is primarily cooled. During the primary cooling, a primary cooling end temperature may be controlled to 670 to 750 $^{\circ}\text{C}$  and performed at an average cooling rate of 1 to 6 $^{\circ}\text{C}/\text{s}$ . When the primary cooling end temperature is lower than 670 $^{\circ}\text{C}$ , a large amount of soft ferrite and bainite in addition to martensite is formed during the cooling process, thereby making the microstructure of the surface layer portion non-uniform, which may deteriorate bending properties. When the primary cooling end temperature exceeds 750 $^{\circ}\text{C}$ , the temperature difference between the primary cooling end temperature and the secondary cooling end temperature  $T_f$  becomes excessively large, thereby causing a rapid phase transformation, which may result in poor product shape. The lower limit of the primary cooling end temperature is more preferably 680 $^{\circ}\text{C}$ . The upper limit of the primary cooling end temperature is more preferably 740 $^{\circ}\text{C}$ . When the primary average cooling rate is less than 1 $^{\circ}\text{C}/\text{s}$ , the ferrite is formed during the cooling, making it impossible to secure the level of strength targeted by the present disclosure. When the primary average cooling rate exceeds 6 $^{\circ}\text{C}/\text{s}$ , the average cooling rate during the subsequent secondary cooling decreases, thereby increasing the fraction of the low-temperature transformation phases other than martensite. As a result, the level of strength targeted by the present disclosure may not be secured. The lower limit of the primary average cooling rate is more preferably 2 $^{\circ}\text{C}/\text{s}$ . The upper limit of the primary average cooling rate is more preferably 5 $^{\circ}\text{C}/\text{s}$ .

**[0077]** Subsequently, the primarily cooled cold-rolled steel sheet is secondarily cooled. The secondary cooling is intended to secure one or more of the main phases of the present disclosure, namely martensite and tempered martensite. During the secondary cooling, the secondary cooling end temperature  $T_f$  may be controlled to 110 to

300°C and performed at an average cooling rate of 30 to 300°C/s. When the secondary cooling end temperature  $T_f$  is below 110°C, the shape defects are caused by rapid phase transformation, and there is a disadvantage that continuous production is difficult due to strip meandering problems. When the secondary cooling end temperature  $T_f$  exceeds 300°C, it may be difficult to secure the strength targeted by the present disclosure. The lower limit of the secondary cooling end temperature is more preferably 115°C, even more preferably 120°C, and most preferably 130°C. The upper limit of the secondary cooling end temperature is more preferably 290°C, even more preferably 280°C, and most preferably 270°C. When the secondary average cooling rate is less than 30°C/s, soft ferrite transformation occurs during cooling, making it difficult to secure the target strength. When the secondary average cooling rate exceeds 300°C/s, the product shape may become defective due to rapid phase transformation. The lower limit of the secondary average cooling rate is more preferably 35°C/s, even more preferably 40°C/s, and most preferably 45°C/s. The upper limit of the secondary average cooling rate is more preferably 290°C/s, even more preferably 280°C/s, and most preferably 270°C/s.

**[0078]** During the secondary cooling,  $M_f$ -secondary cooling end temperature  $T_f$  may be controlled to be 130°C or lower. When the  $M_f$ - $T_f$  exceeds 130°C, the spacing of the martensite laths becomes excessively dense, and as the structure is composed of a large amount of deformation, the yield strength increases, making it difficult to secure the target yield ratio. The  $M_f$ - $T_f$  is more preferably 120°C or lower. Meanwhile, the  $M_s$  refers to the temperature at which the martensite transformation ends upon cooling, and may be calculated using Equation 4 below.

$$M_f(^{\circ}\text{C}) = 431 - 412C - 17.4\text{Si} - 47.4\text{Mn} - 20.9\text{Cr} - 17.0\text{Mo} + 49.2\text{Nb} + 95.0\text{Ti} + 202B \quad [\text{Equation 4}]$$

**[0079]** Thereafter, the secondary cooled cold-rolled steel sheet is reheated and then subjected to overaging treatment. Through the reheating and overaging treatment, the martensite obtained by the above-described rapid cooling process is transformed into tempered martensite, thereby increasing the yield strength. During the overaging treatment, an overaging treatment temperature (H) may be controlled to 100 to 250°C and performed for 5 to 12 minutes. When the overaging treatment temperature is below 100°C, there is a disadvantage that tempering is not sufficiently performed, resulting in low yield strength and inability to secure sufficient toughness. When the overaging treatment temperature exceeds 250°C, there is a disadvantage that bendability becomes inferior due to the precipitation and coarsening of large amounts of carbides. The lower limit of the overaging treatment temperature is more preferably 110°C, even more preferably 120°C, and most preferably 130°C. The upper limit of the overaging treatment temperature is more preferably 245°C, even more preferably 240°C, and most preferably 235°C. When the overaging treatment time is less than 5 minutes, the tempering is not sufficiently performed, and the yield strength may be lowered. When the overaging treatment time exceeds 12 minutes, carbides may coarsen due to excessive tempering, which may result in deterioration of bending properties. The lower limit of the overaging treatment time is more preferably 5.5 minutes, even more preferably 6.0 minutes, and most preferably 6.5 minutes. The upper limit of the overaging treatment time is more preferably 11.5 minutes, even more preferably 11 minutes, and most preferably 10.5 minutes.

**[0080]** During the overaging treatment, the overaging treatment temperature H - secondary cooling end temperature  $T_f$  may be controlled to be 100°C or lower. When the overaging treatment temperature H-the secondary cooling end temperature  $T_f$  exceeds 100°C, the excessive tempering occurs, increasing the yield strength and making it difficult to secure the target low yield ratio. The over-aging treatment temperature H - secondary cooling end temperature  $T_f$  is preferably 90°C or lower.

**[0081]** Subsequently, the overaged cold-rolled steel sheet is subjected to temper rolling (skin pass mill (SPM)) with a rolling force of 500 to 1000 tons. The temper rolling enables control of the surface roughness  $R_{sk}$ . When the rolling force during the temper rolling is less than 500 tons, the load is low, making it difficult to control the surface roughness  $R_{sk}$ , and when the rolling force exceeds 1000 tons, the surface work hardening is severe, which may result in inferior bending properties. The lower limit of the rolling force during the temper rolling is more preferably 550 tons, and even more preferably 600 tons. The upper limit of the rolling force during the temper rolling is more preferably 950 tons, and even more preferably 900 tons.

**[0082]** Subsequently, the temper-rolled cold-rolled steel sheet is tension-leveled (T/L) with an elongation of 0.030 to 0.50%. The tension leveling is intended to correct the shape of the steel sheet. When the elongation is less than 0.030% during the tension leveling, the shape correction may be difficult. When the elongation exceeds 0.50% during the tension leveling, the work hardening may become severe, and the bending properties may deteriorate. The lower limit of the elongation during the tension leveling is more preferably 0.050%, and even more preferably 0.10%. The upper limit of the elongation during the tension leveling is more preferably 0.40%, and even more preferably 0.35%.

**[0083]** Meanwhile, after the tension leveling, a step of forming a coating layer on at least one surface of the cold-rolled steel sheet may be additionally included. The present disclosure does not specifically limit the method of forming the coating layer, and any method commonly used in the relevant technical field may be used. However, as an example, the coating layer may be an electro-galvanized layer.

Mode for Invention

**[0084]** Hereinafter, the present disclosure will be described in more detail with reference to Examples. However, the description of these Examples is provided only for illustrating the implementation of the present disclosure, and is not limited the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and the matters reasonably inferred therefrom.

(Example)

**[0085]** A slab having the alloy composition listed in Table 1 below was heated at 1200°C, and the heated slab was finish hot-rolled at 900°C to obtain a hot-rolled steel sheet, followed by coiling at 450°C. Subsequently, the coiled hot-rolled steel sheet was cold-rolled under the conditions listed in Table 2 below to obtain a cold-rolled steel sheet. Thereafter, a 1.4 mm thick cold-rolled steel sheet was manufactured by continuous annealing, primary cooling, secondary cooling, reheating/overaging treatment, temper rolling, and tension leveling under the conditions listed in Tables 2 and 3 below. Meanwhile, the conditions listed in Tables 2 and 3 below were based on the surface temperature of the steel sheet.

**[0086]** For the cold-rolled steel sheet manufactured in this manner, the microstructure, number fraction having a kernel average misorientation (KAM) value of 0 to 1.0°, residual stress in a surface layer portion, surface roughness, and mechanical properties were measured, and the results were shown in Tables 4 and 5 below.

**[0087]** The types and fractions of the microstructures were observed through a scanning electron microscope (SEM) and an optical microscope (OM) with respect to a surface layer portion (a position 20 μm from a surface in a thickness direction) and a central portion (a position of 1/4t, where t is a thickness of the steel material) of the steel sheet, and the fraction of each phase was analyzed three times through image analysis to calculate an average value.

**[0088]** The number fraction of a region having a KAM value of 0 to 1.0° was measured three times at 2,000× magnification using electron backscatter diffraction (EBSD) (confidence index (CI) ≥ 0.3) with respect to a position of 1/4t (where t is a thickness of the steel material), and the average value was calculated. In this case, the number fraction of the region having the KAM value of 0 to 5.0° was considered as 100% during EBSD measurement.

**[0089]** The residual stress in the surface layer portion was measured five times using XRD (X-ray generator 40 kV, 30mA, scan step 0.0194°, scan speed 1.247°/min, scan mode 0D(continuous), scan axis 2θ/θ, wavelength  $K_{\alpha 1}$  0.154nm), and then, the average value excluding the maximum (Max) and minimum (Min) values was calculated.

**[0090]** The surface roughness  $R_{sk}$  ( $P_c$ ) was measured five times using a contact-type 2D roughness meter, and the average value was calculated after excluding maximum (Max) and minimum (Min) values.

**[0091]** The yield strength, tensile strength, yield ratio, and total elongation were measured by processing the cold-rolled steel sheet into a specimen conforming to JIS Standard No. 5 and performing a tensile test under conditions of a test speed of 28 mm/min.

**[0092]** Bendability  $R/t$  was evaluated by processing the cold-rolled steel sheet into a specimen having a width of 100 mm and a length of 30 mm, followed by performing a 90° bending test at a test speed of 800 mm/min. Thereafter, the presence or absence of cracks in the bent portion was confirmed using a stereoscopic microscope, and a minimum bending radius (R value of a die) at which no cracks occurred was obtained by dividing the minimum bending radius by the thickness (mm) of the specimen.

**[0093]** For the hardness deviation, a micro-hardness tester was used at the 1/4t (t thickness of a steel material) position on the steel sheet. As illustrated in FIG. 1, a total of 50 points were measured using a load of 1g, with 5 points vertically × 10 points horizontally, and the difference between the maximum (Max) and minimum (Min) values was calculated.

**[0094]** The hole expansion ratio (HER) was measured according to the ISO 16330 standard, and the hole was sheared with a clearance of 12% using a 10mm diameter punch.

[Table 1]

| Steel Grade No .                                                         | Alloy Composition (wt%) |      |      |       |        |       |       |       |       |       |        | X    | Y   | Y/X |
|--------------------------------------------------------------------------|-------------------------|------|------|-------|--------|-------|-------|-------|-------|-------|--------|------|-----|-----|
|                                                                          | C                       | Si   | Mn   | P     | S      | Al    | Cr    | Mo    | Nb    | Ti    | B      |      |     |     |
| 1                                                                        | 0.24                    | 0.11 | 1.81 | 0.010 | 0.0009 | 0.025 | 0.06  | 0.07  | 0.031 | 0.025 | 0.0020 | 0.36 | 158 | 441 |
| 2                                                                        | 0.23                    | 0.21 | 1.91 | 0.011 | 0.0011 | 0.031 | 0.14  | 0.08  | 0.025 | 0.030 | 0.0019 | 0.36 | 161 | 449 |
| 3                                                                        | 0.25                    | 0.06 | 1.75 | 0.014 | 0.0008 | 0.030 | 0.10  | 0.06  | 0.027 | 0.023 | 0.0021 | 0.37 | 153 | 413 |
| 4                                                                        | 0.24                    | 0.15 | 1.70 | 0.012 | 0.0015 | 0.031 | 0.11  | 0.10  | 0.025 | 0.034 | 0.0019 | 0.36 | 153 | 425 |
| 5                                                                        | 0.24                    | 0.21 | 1.86 | 0.010 | 0.0007 | 0.030 | 0.21  | 0.06  | 0.041 | 0.040 | 0.0015 | 0.36 | 181 | 499 |
| 6                                                                        | 0.17                    | 0.25 | 1.95 | 0.011 | 0.0014 | 0.039 | 0.25  | 0.15  | 0.031 | 0.021 | 0.0025 | 0.30 | 187 | 617 |
| 7                                                                        | 0.25                    | 0.15 | 2.80 | 0.012 | 0.0012 | 0.035 | 0.15  | 0.09  | 0.025 | 0.025 | 0.0021 | 0.2  | 197 | 464 |
| 8                                                                        | 0.25                    | 0.75 | 2.00 | 0.015 | 0.0010 | 0.030 | 0.10  | 0.09  | 0.025 | 0.020 | 0.0020 | 0.41 | 179 | 438 |
| 9                                                                        | 0.29                    | 0.11 | 2.00 | 0.010 | 0.0010 | 0.035 | 0.15  | 0.08  | 0.029 | 0.027 | 0.0024 | 0.42 | 178 | 426 |
| 10                                                                       | 0.21                    | 0.15 | 1.20 | 0.010 | 0.0011 | 0.041 | 0.07  | 0.04  | 0.030 | 0.025 | 0.0025 | 0.30 | 136 | 454 |
| 11                                                                       | 0.20                    | 0.11 | 1.55 | 0.007 | 0.0010 | 0.031 | 0.001 | 0.001 | 0.021 | 0.020 | 0.0020 | 0.30 | 120 | 400 |
| X = C+Mn/20+Si/30+2P+4S                                                  |                         |      |      |       |        |       |       |       |       |       |        |      |     |     |
| Y = 48.8+49logC+35.1Mn+25.9Si+14.5Ni+9.6Cu+76.5Cr+105.9Mo+1325Nb+10 000B |                         |      |      |       |        |       |       |       |       |       |        |      |     |     |

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[Table 2]

| Division                                                                                                                                                                                             | Steel grade No. | Ar3 (°C) | Ms (°C) | Cold Reduction Ratio (%) | Cold Rolling Roll Roughness (μm) | Ac3 (°C) | Annealing Temperature (°C) | Primary Cooling End Temperature (°C) | Primary Average Cooling Rate (°C/s) |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------|---------|--------------------------|----------------------------------|----------|----------------------------|--------------------------------------|-------------------------------------|
| Inventive Example 1                                                                                                                                                                                  | 1               | 818      | 374     | 56                       | 4.5                              | 788      | 856                        | 715                                  | 3                                   |
| Inventive Example 2                                                                                                                                                                                  | 2               | 825      | 367     | 56                       | 4.5                              | 790      | 859                        | 705                                  | 3                                   |
| Inventive Example 3                                                                                                                                                                                  | 3               | 813      | 375     | 56                       | 4.5                              | 785      | 846                        | 712                                  | 3                                   |
| Inventive Example 4                                                                                                                                                                                  | 4               | 820      | 373     | 56                       | 4.5                              | 793      | 852                        | 716                                  | 3                                   |
| Inventive Example 5                                                                                                                                                                                  | 5               | 822      | 363     | 56                       | 4.5                              | 790      | 860                        | 725                                  | 3                                   |
| Comparative Example 1                                                                                                                                                                                | 6               | 842      | 386     | 56                       | 4.5                              | 800      | 842                        | 731                                  | 3                                   |
| Comparative Example 2                                                                                                                                                                                | 7               | 818      | 335     | 56                       | 4.5                              | 761      | 856                        | 736                                  | 3                                   |
| Comparative Example 3                                                                                                                                                                                | 8               | 845      | 315     | 56                       | 4.5                              | 797      | 850                        | 725                                  | 3                                   |
| Comparative Example 4                                                                                                                                                                                | 9               | 808      | 346     | 56                       | 4.5                              | 772      | 861                        | 715                                  | 3                                   |
| Comparative Example 5                                                                                                                                                                                | 10              | 825      | 403     | 56                       | 4.5                              | 810      | 855                        | 701                                  | 3                                   |
| Comparative Example 6                                                                                                                                                                                | 11              | 824      | 400     | 56                       | 4.5                              | 802      | 875                        | 709                                  | 3                                   |
| Comparative Example 7                                                                                                                                                                                | 1               | 818      | 374     | 35                       | 2.0                              | 788      | 856                        | 712                                  | 3                                   |
| Comparative Example 8                                                                                                                                                                                | 1               | 818      | 374     | 42                       | 1.5                              | 788      | 854                        | 716                                  | 3                                   |
| Comparative Example 9                                                                                                                                                                                | 1               | 818      | 374     | 56                       | 4.5                              | 788      | 780                        | 725                                  | 3                                   |
| Comparative Example 10                                                                                                                                                                               | 1               | 818      | 374     | 56                       | 4.5                              | 788      | 850                        | 645                                  | 3                                   |
| Comparative Example 11                                                                                                                                                                               | 1               | 818      | 374     | 60                       | 4.5                              | 788      | 861                        | 716                                  | 3                                   |
| Comparative Example 12                                                                                                                                                                               | 1               | 818      | 374     | 56                       | 4.5                              | 788      | 859                        | 720                                  | 3                                   |
| Comparative Example 13                                                                                                                                                                               | 1               | 818      | 374     | 56                       | 4.5                              | 788      | 864                        | 718                                  | 3                                   |
| Comparative Example 14                                                                                                                                                                               | 3               | 813      | 375     | 56                       | 4.5                              | 785      | 854                        | 721                                  | 3                                   |
| Comparative Example 15                                                                                                                                                                               | 3               | 813      | 375     | 56                       | 4.5                              | 785      | 865                        | 715                                  | 3                                   |
| Ar3(°C) = 910 - 203√C + 44.7Si + 31.5Mo<br>Ms(°C) = 539 - 423C - 30.4Mn - 7.5Si + 30Al - 17.7Ni - 12.1Cr - 7.5Mo<br>Ac3(°C) = 875 - 206C + 26.2Si - 25.0Mn - 12.3Cr + 9.12Mo + 50.2Nb + 148Ti - 131B |                 |          |         |                          |                                  |          |                            |                                      |                                     |

[Table 3]

| Division                                                         | Steel grade No. | Mf (°C) | Secondary Cooling End Temperature (Tf) (°C) | Secondary Average Cooling Rate (°C/s) | Mf-Tf (°C) | Reheating/Overaging Treatment Temperature (H) (°C) | Overaging Treatment Time (minute) | H-Tf (°C) | Temper Rolling Force (ton) | Tension Leveling Elongation (%) |
|------------------------------------------------------------------|-----------------|---------|---------------------------------------------|---------------------------------------|------------|----------------------------------------------------|-----------------------------------|-----------|----------------------------|---------------------------------|
| Inventive Example 1                                              | 1               | 246     | 175                                         | 61                                    | 71         | 185                                                | 8.4                               | 10        | 650                        | 0.05                            |
| Inventive Example 2                                              | 2               | 242     | 180                                         | 60                                    | 62         | 170                                                | 8.7                               | -10       | 650                        | 0.05                            |
| Inventive Example 3                                              | 3               | 245     | 195                                         | 58                                    | 50         | 185                                                | 8.7                               | -10       | 650                        | 0.05                            |
| Inventive Example 4                                              | 4               | 250     | 200                                         | 59                                    | 50         | 176                                                | 8.5                               | -24       | 650                        | 0.05                            |
| Inventive Example 5                                              | 5               | 241     | 194                                         | 60                                    | 47         | 175                                                | 8.6                               | -19       | 650                        | 0.05                            |
| Comparative Example 1                                            | 6               | 260     | 210                                         | 61                                    | 50         | 195                                                | 8.3                               | -15       | 650                        | 0.05                            |
| Comparative Example 2                                            | 7               | 192     | 155                                         | 62                                    | 37         | 210                                                | 8.1                               | 55        | 650                        | 0.15                            |
| Comparative Example 3                                            | 8               | 220     | 16                                          | 63                                    | 52         | 191                                                | 8.2                               | 23        | 650                        | 0.05                            |
| Comparative Example 4                                            | 9               | 215     | 152                                         | 62                                    | 63         | 215                                                | 8.6                               | 63        | 650                        | 0.25                            |
| Comparative Example 5                                            | 10              | 287     | 184                                         | 65                                    | 103        | 195                                                | 9.1                               | 11        | 650                        | 0.05                            |
| Comparative Example 6                                            | 11              | 277     | 195                                         | 63                                    | 82         | 189                                                | 8.9                               | -6        | 650                        | 0.05                            |
| Comparative Example 7                                            | 1               | 246     | 175                                         | 63                                    | 71         | 191                                                | 8.7                               | 16        | 650                        | 0.05                            |
| Comparative Example 8                                            | 1               | 246     | 195                                         | 64                                    | 51         | 189                                                | 8.6                               | -6        | 650                        | 0.05                            |
| Comparative Example 9                                            | 1               | 246     | 180                                         | 62                                    | 66         | 200                                                | 8.5                               | 20        | 650                        | 0.05                            |
| Comparative Example 10                                           | 1               | 246     | 165                                         | 61                                    | 81         | 201                                                | 8.7                               | 36        | 650                        | 0.05                            |
| Comparative Example 11                                           | 1               | 246     | 105                                         | 76                                    | 141        | 185                                                | 8.5                               | 20        | 650                        | 0.25                            |
| Comparative Example 12                                           | 1               | 246     | 85                                          | 70                                    | 161        | 230                                                | 8.6                               | 145       | 650                        | 0.25                            |
| Comparative Example 13                                           | 1               | 246     | 185                                         | 59                                    | 61         | 300                                                | 8.7                               | 115       | 650                        | 0.05                            |
| Comparative Example 14                                           | 3               | 245     | 174                                         | 60                                    | 61         | 195                                                | 8.7                               | 11        | 250                        | 0.55                            |
| Comparative Example 15                                           | 3               | 245     | 189                                         | 61                                    | 56         | 202                                                | 8.6                               | 13        | 650                        | 0.65                            |
| Mf(°C) = 431-412C-17.4Si-47.4Mn-20.9Cr-17.0Mo+49.2Nb+95.0Ti+202B |                 |         |                                             |                                       |            |                                                    |                                   |           |                            |                                 |

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[Table 4]

| 5  | Division               | Microstructure (area%) |                         |                        |                         | Number Fraction of Region Having KAM Value of 0 to 1.0° (%) | Residual Stress in Surface Layer Portion (MPa) | Surface Roughness |     |        |
|----|------------------------|------------------------|-------------------------|------------------------|-------------------------|-------------------------------------------------------------|------------------------------------------------|-------------------|-----|--------|
|    |                        | Surface Layer Portion  |                         | Central Portion        |                         |                                                             |                                                | Rsk               | Pc  | Rsk×Pc |
|    |                        | One or more of F and B | One or more of M and Tm | One or more of F and B | One or more of M and Tm |                                                             |                                                |                   |     |        |
| 10 | Inventive Example 1    | 3                      | 97                      | 1                      | 99                      | 25                                                          | -78                                            | -0.35             | 170 | -60    |
| 15 | Inventive Example 2    | 2                      | 98                      | 1                      | 99                      | 26                                                          | -69                                            | -0.32             | 181 | -58    |
|    | Inventive Example 3    | 3                      | 97                      | 1                      | 99                      | 27                                                          | -72                                            | -0.36             | 191 | -69    |
| 20 | Inventive Example 4    | 2                      | 98                      | 1                      | 99                      | 25                                                          | -81                                            | -0.36             | 184 | -66    |
|    | Inventive Example 5    | 2                      | 98                      | 1                      | 99                      | 26                                                          | -92                                            | -0.37             | 165 | -61    |
| 25 | Comparative Example 1  | 11                     | 89                      | 5                      | 95                      | 32                                                          | -75                                            | -0.39             | 175 | -68    |
|    | Comparative Example 2  | 13                     | 87                      | 1                      | 99                      | 21                                                          | -62                                            | -0.42             | 168 | -71    |
| 30 | Comparative Example 3  | 12                     | 88                      | 1                      | 99                      | 25                                                          | -79                                            | -0.38             | 181 | -69    |
|    | Comparative Example 4  | 2                      | 98                      | 1                      | 99                      | 20                                                          | -62                                            | -0.39             | 172 | -67    |
| 35 | Comparative Example 5  | 15                     | 85                      | 10                     | 90                      | 33                                                          | -75                                            | -0.45             | 178 | -80    |
|    | Comparative Example 6  | 13                     | 87                      | 9                      | 91                      | 32                                                          | -82                                            | -0.44             | 181 | -80    |
| 40 | Comparative Example 7  | 2                      | 98                      | 2                      | 98                      | 20                                                          | -91                                            | -0.73             | 189 | -138   |
|    | Comparative Example 8  | 1                      | 99                      | 1                      | 99                      | 23                                                          | -89                                            | -0.72             | 190 | -137   |
| 45 | Comparative Example 9  | 15                     | 85                      | 10                     | 90                      | 40                                                          | -79                                            | -0.42             | 201 | -84    |
|    | Comparative Example 10 | 18                     | 82                      | 3                      | 97                      | 23                                                          | -84                                            | -0.41             | 185 | -76    |
| 50 | Comparative Example 11 | 17                     | 83                      | 15                     | 85                      | 20                                                          | -69                                            | -0.42             | 189 | -79    |
|    | Comparative Example 12 | 4                      | 96                      | 3                      | 97                      | 20                                                          | -69                                            | -0.48             | 187 | -90    |
| 55 | Comparative Example 13 | 2                      | 98                      | 0                      | 100                     | 32                                                          | -87                                            | -0.39             | 175 | -68    |
|    | Comparative Example 14 | 3                      | 97                      | 2                      | 98                      | 26                                                          | -25                                            | -0.41             | 178 | -73    |

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(continued)

| Division                                                   | Microstructure (area%) |                         |                        |                         | Number Fraction of Region Having KAM Value of 0 to 1.0° (%) | Residual Stress in Surface Layer Portion (MPa) | Surface Roughness |     |        |
|------------------------------------------------------------|------------------------|-------------------------|------------------------|-------------------------|-------------------------------------------------------------|------------------------------------------------|-------------------|-----|--------|
|                                                            | Surface Layer Portion  |                         | Central Portion        |                         |                                                             |                                                | Rsk               | Pc  | Rsk×Pc |
|                                                            | One or more of F and B | One or more of M and Tm | One or more of F and B | One or more of M and Tm |                                                             |                                                |                   |     |        |
| Comparative Example 15                                     | 2                      | 98                      | 1                      | 99                      | 25                                                          | -15                                            | -0.38             | 182 | -69    |
| F Ferrite, B Bainite, M Martensite, TM Tempered Martensite |                        |                         |                        |                         |                                                             |                                                |                   |     |        |

[Table 5]

| Division               | Yield Strength (MPa) | Tensile Strength (MPa) | Yield Ratio | Elongation (%) | Bendability (R/t) | Strength Deviation (MPa) | Hole Expansion Ratio (%) |
|------------------------|----------------------|------------------------|-------------|----------------|-------------------|--------------------------|--------------------------|
| Inventive Example 1    | 1106                 | 1532                   | 0.72        | 6              | 2.5               | 189                      | 45                       |
| Inventive Example 2    | 1200                 | 1542                   | 0.78        | 6              | 2.5               | 165                      | 51                       |
| Inventive Example 3    | 1095                 | 1526                   | 0.72        | 6              | 2.5               | 145                      | 50                       |
| Inventive Example 4    | 1168                 | 1521                   | 0.77        | 6              | 2.5               | 136                      | 50                       |
| Inventive Example 5    | 1261                 | 1567                   | 0.80        | 6              | 2.5               | 159                      | 49                       |
| Comparative Example 1  | 1025                 | 1425                   | 0.72        | 7              | 2.5               | 25                       | 36                       |
| Comparative Example 2  | 1360                 | 1567                   | 0.87        | 5              | 3.2               | 189                      | 34                       |
| Comparative Example 3  | 1105                 | 1536                   | 0.72        | 6              | 3.9               | 159                      | 41                       |
| Comparative Example 4  | 1401                 | 1581                   | 0.89        | 4              | 3.9               | 186                      | 40                       |
| Comparative Example 5  | 998                  | 1405                   | 0.71        | 8              | 2.5               | 265                      | 22                       |
| Comparative Example 6  | 1025                 | 1425                   | 0.72        | 9              | 2.5               | 259                      | 25                       |
| Comparative Example 7  | 1125                 | 1535                   | 0.73        | 6              | 4.3               | 145                      | 45                       |
| Comparative Example 8  | 1150                 | 1542                   | 0.75        | 6              | 4.3               | 139                      | 42                       |
| Comparative Example 9  | 945                  | 1545                   | 0.61        | 5              | 4.6               | 356                      | 18                       |
| Comparative Example 10 | 1089                 | 1501                   | 0.73        | 6              | 4.3               | 189                      | 28                       |

(continued)

| Division               | Yield Strength (MPa) | Tensile Strength (MPa) | Yield Ratio | Elongation (%) | Bendability (R/t) | Strength Deviation (MPa) | Hole Expansion Ratio (%) |
|------------------------|----------------------|------------------------|-------------|----------------|-------------------|--------------------------|--------------------------|
| Comparative Example 11 | 1325                 | 1589                   | 0.83        | 5              | 3.2               | 175                      | 45                       |
| Comparative Example 12 | 1350                 | 1559                   | 0.87        | 5              | 3.2               | 169                      | 51                       |
| Comparative Example 13 | 1295                 | 1468                   | 0.88        | 6              | 4.3               | 125                      | 58                       |
| Comparative Example 14 | 1105                 | 1525                   | 0.72        | 6              | 4.3               | 157                      | 45                       |
| Comparative Example 15 | 1101                 | 1536                   | 0.72        | 6              | 4.3               | 168                      | 43                       |

**[0095]** As can be seen from Tables 1 to 5 above, Inventive Examples 1 to 5, which satisfy the conditions proposed by the present disclosure, secure the mechanical properties targeted by the present disclosure.

**[0096]** On the other hand, in the case of Comparative Examples 1 to 15, which do not satisfy the alloy composition or manufacturing conditions proposed by the present disclosure, it could be seen that the mechanical properties are inferior.

**[0097]** FIGS. 2 and 3 are scanning electron microscope (SEM) images of Inventive Example 1 and Comparative Example 9, respectively. Inventive Example 1 is composed predominantly of martensite and tempered martensite and exhibits a uniform microstructure, whereas Comparative Example 9, which does not satisfy the annealing temperature proposed in the present disclosure, has martensite and tempered martensite as major structure and contains a large amount of ferrite, which is a soft phase.

## Claims

### 1. A cold-rolled steel sheet, comprising:

by wt%, carbon (C): 0.180 to 0.280%, silicon (Si): 0.030 to 0.70%, manganese (Mn): 1.50 to 2.40%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, boron (B): 0.00050 to 0.0050%, phosphorus (P): 0.030% or less (excluding 0%), sulfur (S): 0.00350% or less (excluding 0%), nitrogen (N): 0.010% or less (excluding 0%), aluminum (Al): 0.010 to 0.10%, niobium (Nb): 0.0030 to 0.050%, and titanium (Ti): 0.0050 to 0.050%, and the balance being Fe and unavoidable impurities, and satisfying Relational Equations 1 to 3 below, the cold-rolled steel sheet comprising:  
a central portion; and  
a surface layer portion formed on an outer side of the central portion in a thickness direction, wherein a residual stress of the surface layer portion is -30 MPa or less, and  
a surface roughness (Rsk) of the surface layer portion is -0.7 or more.

$$0.31 \leq X = C + Mn/20 + Si/30 + 2P + 4S \leq 0.40 \quad [\text{Relational Expression 1}]$$

$$100 \leq Y = 48.8 + 49\log C + 35.1Mn + 25.9Si + 14.5Ni + 9.6Cu + 76.5Cr + 105.9Mo + 1325Nb + 10000B \leq 195 \quad [\text{Relational Expression 2}]$$

$$[\text{Relational Equation 3}] \quad 270 \leq Y/X \leq 600$$

where the content of each alloying element in Relational Equations 1 to 3 above is in wt%.

### 2. The cold-rolled steel sheet of claim 1, wherein the surface layer portion is a region extending from a surface of a steel material to 20 $\mu\text{m}$ in a thickness direction.

3. The cold-rolled steel sheet of claim 1, wherein the microstructure of the central portion includes, in area %, a total of 5% or less (including 0%) of one or more of ferrite and bainite, and the balance being one or more of martensite and tempered martensite.
- 5 4. The cold-rolled steel sheet of claim 1, wherein the microstructure of the surface layer portion includes, in area %, a total of 10% or less (excluding 0%) of one or more of ferrite and bainite, and the balance being one or more of martensite and tempered martensite.
- 10 5. The cold-rolled steel sheet of claim 1, wherein in the cold-rolled steel sheet, upon measuring EBSD, when a number fraction of a region having a KAM value of 0 to 5.0° is set to 100%, a number fraction of a region having a KAM value of 0 to 1.0° at a 1/4 position in the thickness direction is set to 22 to 30%.
- 15 6. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a product of Rsk and Pc of -130 or greater.
- 20 7. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a yield strength (YS) of 1000 to 1300 MPa, a tensile strength (TS) of 1470 to 1670 MPa, a yield ratio (YS/TS) of 0.85 or less, and an elongation (EI) of 4 to 10%.
- 25 8. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a yield strength (YS) × elongation (EI) of 4000 MPa% or more.
9. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a bendability (R/t) of 3.5 or less.
- 30 10. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a hole expansion ratio (HER) of 30% or more.
11. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a hardness deviation of 250 Hv or less at a 1/4 position in the thickness direction.
- 35 12. The cold-rolled steel sheet of claim 1, wherein the cold-rolled steel sheet has a coating layer formed on at least one surface.
13. A manufacturing method of a cold-rolled steel sheet, comprising:

heating a slab comprising, by wt%, carbon (C): 0.180 to 0.280%, silicon (Si): 0.030 to 0.70%, manganese (Mn): 1.50 to 2.40%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, boron (B): 0.00050 to 0.0050%, phosphorus (P): 0.030% or less (excluding 0%), sulfur (S): 0.00350% or less (excluding 0%), nitrogen (N): 0.010% or less (excluding 0%), aluminum (Al): 0.010 to 0.10%, niobium (Nb): 0.0030 to 0.050%, and titanium (Ti): 0.0050 to 0.050%, and the balance being Fe and unavoidable impurities, and satisfying Relational Equations 1 to 3 below;  
obtaining a hot-rolled steel sheet by finish hot rolling the heated slab;  
coiling the hot-rolled steel sheet;  
cold rolling the coiled hot-rolled steel sheet using a roll having a surface roughness (Ra) of 2.5 μm or more to obtain the cold-rolled steel sheet;  
continuously annealing the cold-rolled steel sheet;  
primarily cooling the continuously annealed cold-rolled steel sheet;  
secondarily cooling the primarily cooled cold-rolled steel sheet;  
reheating the secondarily cooled cold-rolled steel sheet and then overaging-treating the cold-rolled steel sheet;  
temper-rolling the overaging-treated cold-rolled steel sheet with a rolling force of 500 to 1000 tons; and  
tension-leveling the temper-rolled cold-rolled steel sheet with an elongation of 0.030 to 0.50%.

$$0.31 \leq X = C + Mn/20 + Si/30 + 2P + 4S \leq 0.40 \quad [\text{Relational Expression 1}]$$

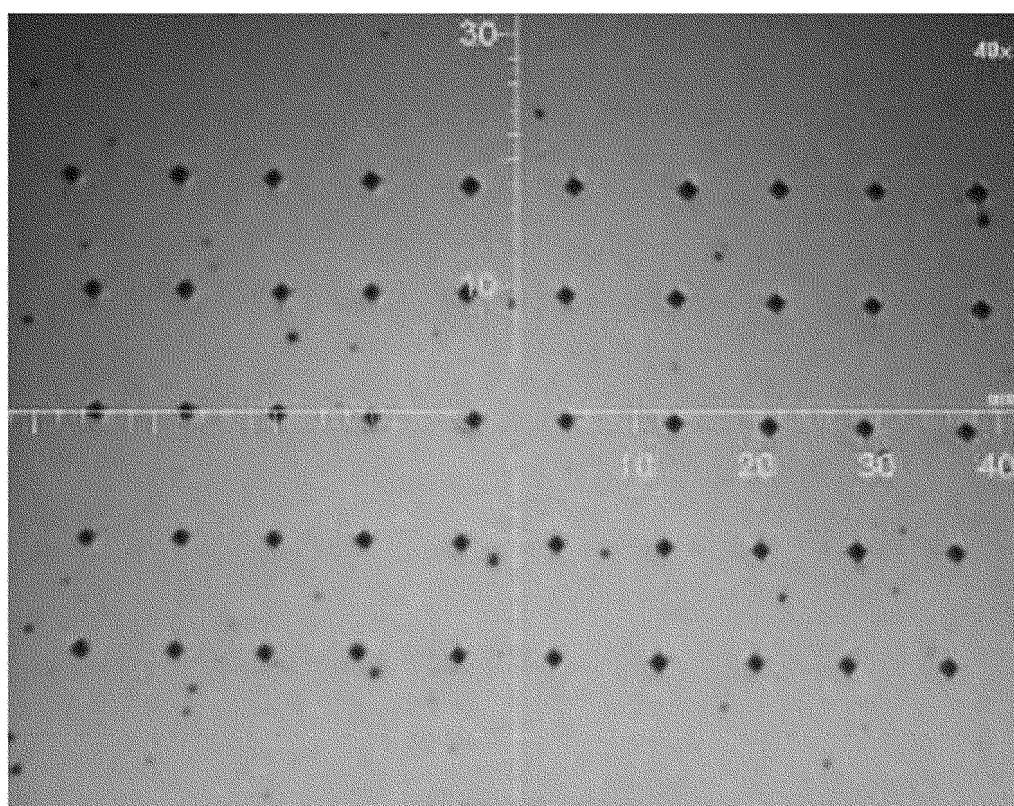
$$100 \leq Y = 48.8 + 49\log C + 35.1Mn + 25.9Si + 14.5Ni + 9.6Cu + 76.5Cr + 105.9Mo + 1325Nb + 10000B \leq 200 \quad [\text{Relational Expression 2}]$$

[Relational Equation 3]  $270 \leq Y/X \leq 600$

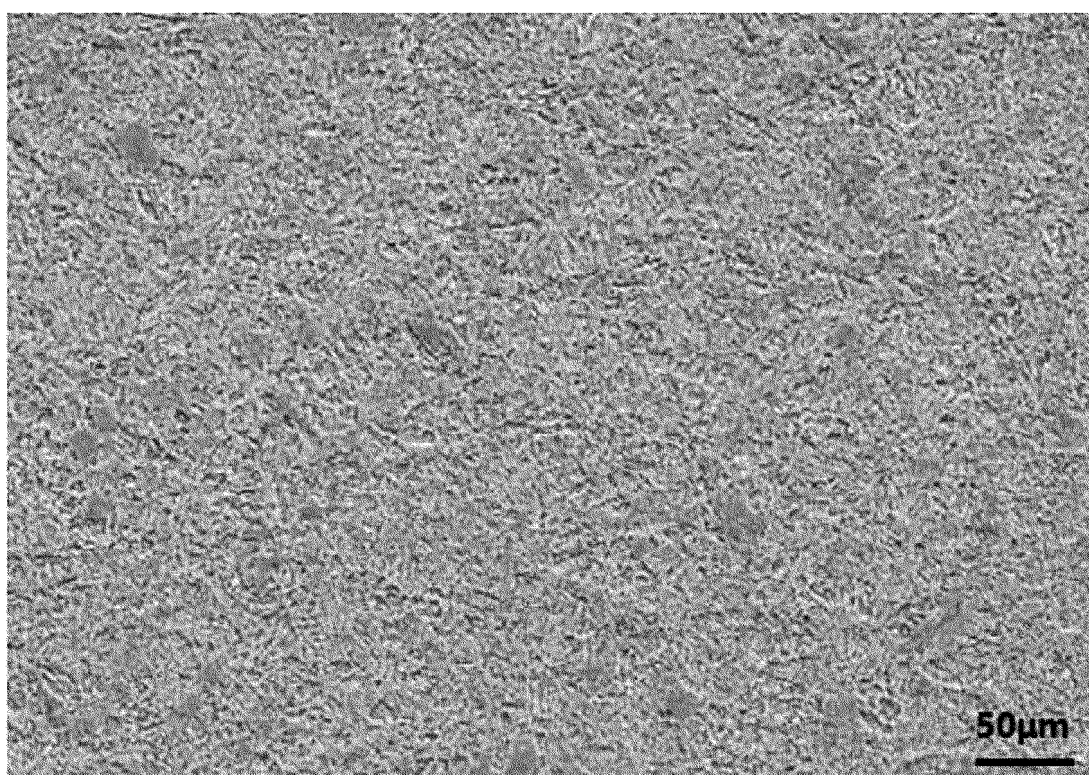
where the content of each alloying element in Relational Equations 1 to 3 above is in wt%.

14. The manufacturing method of claim 13, wherein the heating of the slab is performed at 1100 to 1300°C.
15. The manufacturing method of claim 13, wherein the finish hot rolling is performed at Ar3 to Ar3+120°C.
16. The manufacturing method of claim 13, wherein the coiling is performed at Ms to 600°C.
17. The manufacturing method of claim 13, wherein the cold rolling is performed at a cold reduction ratio of 45 to 70%.
18. The manufacturing method of claim 13, wherein the continuous annealing is performed at Ac3+20°C to Ac3+80°C.
19. The manufacturing method of claim 13, wherein the continuous annealing is performed for 30 to 230 seconds.
20. The manufacturing method of claim 13, wherein during the primary cooling, a primary cooling end temperature is controlled to 670 to 750°C and the primary cooling is performed at an average cooling rate of 1 to 6°C/s.
21. The manufacturing method of claim 13, wherein during the secondary cooling, a secondary cooling end temperature (Tf) is controlled to 110 to 300°C and the secondary cooling is performed at an average cooling rate of 30 to 300°C/s.
22. The manufacturing method of claim 13, wherein during the secondary cooling, Mf-secondary cooling end temperature (Tf) is controlled to be 130°C or lower.
23. The manufacturing method of claim 13, wherein during the overaging treatment, an overaging treatment temperature (H) is controlled to 100 to 250°C and performed for 5 to 12 minutes.
24. The manufacturing method of claim 13, wherein during the overaging treatment, the overaging treatment temperature (H) - secondary cooling end temperature (Tf) is controlled to be 100°C or lower.
25. The manufacturing method of claim 13, further comprising:  
after the tension leveling, forming a coating layer on at least one surface of the cold-rolled steel sheet.

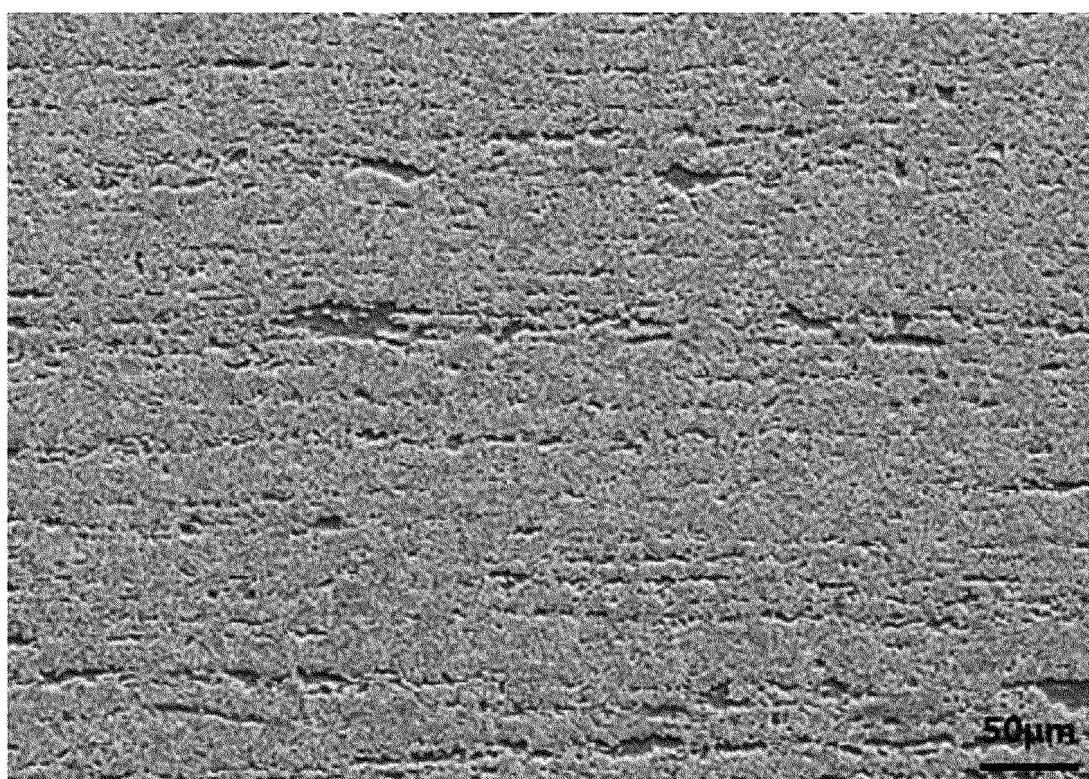
[Fig. 1]



[Fig. 2]



[Fig. 3]



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/019512

## A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; C22C 38/22(2006.01)i; C22C 38/32(2006.01)i; C22C 38/00(2006.01)i; C22C 38/06(2006.01)i;  
C22C 38/28(2006.01)i; C22C 38/26(2006.01)i; C25D 3/22(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 38/38(2006.01); B21C 47/02(2006.01); C21D 1/18(2006.01); C21D 8/02(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: 과시효(over aging), 표면조도(Surface Roughness), 연속소둔(Continuous Annealing), 냉각(Cooling), 텐션레벨링(Tension Leveling), 조질압연(Skin Pass Rolling)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                           | Relevant to claim No. |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | KR 10-2023-0089785 A (POSCO) 21 June 2023 (2023-06-21)<br>See paragraphs [0113]-[0126] and [0189]-[0197], claims 1 and 8 and tables 2 and 4. | 1-21,23-25            |
| A         |                                                                                                                                              | 22                    |
| Y         | KR 10-2004-0063018 A (YOUN, Myung Joong) 12 July 2004 (2004-07-12)<br>See paragraphs [0018] and [0027] and table 1.                          | 1-21,23-25            |
| A         | JP 2014-196557 A (KOBELITE LTD.) 16 October 2014 (2014-10-16)<br>See paragraphs [0048]-[0053] and [0071] and claims 1-5.                     | 1-25                  |
| A         | KR 10-2012-0101596 A (JFE STEEL CORPORATION) 13 September 2012 (2012-09-13)<br>See paragraph [0065] and claims 1-4.                          | 1-25                  |
| A         | KR 10-2023-0087773 A (POSCO) 19 June 2023 (2023-06-19)<br>See claim 1.                                                                       | 1-25                  |

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

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

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