



(11)

EP 4 826 080 A1

(12)

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

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

(21) Application number: **24904325.8**

(22) Date of filing: **16.12.2024**

(51) International Patent Classification (IPC):
C22C 38/38 ^(2006.01) **C22C 38/22** ^(2006.01)
C22C 38/32 ^(2006.01) **C22C 38/06** ^(2006.01)
C22C 38/00 ^(2006.01) **C22C 38/28** ^(2006.01)
C22C 38/26 ^(2006.01) **C21D 8/02** ^(2006.01)

(52) Cooperative Patent Classification (CPC):
C21D 8/02; C22C 38/00; C22C 38/06; C22C 38/22;
C22C 38/26; C22C 38/28; C22C 38/32; C22C 38/38

(86) International application number:
PCT/KR2024/020434

(87) International publication number:
WO 2025/127760 (19.06.2025 Gazette 2025/25)

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

(30) Priority: **15.12.2023 KR 20230183867**

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

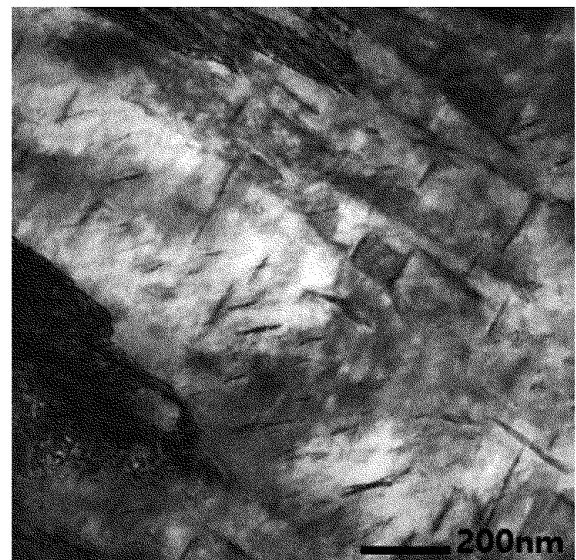
(72) Inventors:
• **KONG, Jong-Pan**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **BANG, Chan-Woo**
Gwangyang-si, Jeollanam-do 57807 (KR)
• **HAN, Sang-Ho**
Gwangyang-si, Jeollanam-do 57807 (KR)

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

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

(57) One aspect of the present invention is that a cold rolled steel sheet and a method for manufacturing same are to be provided. One advantageous aspect of the present invention is that an ultra-high strength cold rolled steel sheet and a method for manufacturing same are to be provided, the cold rolled steel sheet having a tensile strength of 1470 MPa or higher and excellent bending properties, spot weldability, and corrosion resistance while having excellent formability.

[Fig. 1]



EP 4 826 080 A1

Description

Technical Field

5 **[0001]** The present disclosure relates to a cold-rolled steel sheet and a method for manufacturing the same, and more particularly, to a cold-rolled steel sheet suitable for use as a steel material for automobile reinforcements such as bumper beams and sill side beams, or as a steel material for protecting electric vehicle battery cases such as side frames and cross members, and a method for manufacturing the same.

10 Background Art

[0002] In the case of steel materials primarily used for reinforcement parts related to the crash safety of automobile passengers, they are required to have high processing characteristics, particularly excellent bendability, and ultra-high strength. To this end, research on ultra-high-strength steel with a tensile strength of 1470 MPa or higher using a martensitic single phase and methods for manufacturing the same has been actively conducted.

15 **[0003]** Recently, the Hot Press Forming (HPF) method has been developed, which secures the required strength through water cooling after forming a material using a die in a high-temperature environment where forming is easy. Because it can secure high strength for the same thickness, the HPF method is widely used in parts manufacturing, but it has the disadvantage of requiring excessive facility investment and an increase in processing costs. Therefore, there is a need to develop materials for cold stamping and roll forming. That is, the development of an ultra-high-strength cold-rolled steel sheet is required, which is suitable for use as a material for cold stamping and roll forming, has high strength and a high yield ratio to ensure crash performance, and has excellent bendability for part forming, spot weldability for part assembly, and corrosion resistance for a long part lifespan.

25 **[0004]** A representative conventional technology for this method is Patent Document 1. Patent Document 1 relates to a steel having a martensitic single-phase structure, comprising C: 0.25-0.4%, Si: 1.0% or less, Mn: 1.5-2.5%, P: 0.02% or less, S: 0.003% or less, Al: 0.01-0.1%, N: 0.005% or less, B: 0.0005-0.005%, and also comprising Ti: 0.005-0.1%, Nb: 0.005-0.1%, with a total of 0.005-0.1%. It discloses that this can be obtained by heating and holding in a temperature range of the Ae3 transformation point or higher and 900°C or lower, then rapidly cooling to 200°C or lower at an average cooling rate of 300°C/s, and subsequently tempering at 250°C or lower. However, in the case of Patent Document 1, there is a problem in that rapid cooling (water cooling) causes poor shape (flatness), leading to defects during forming.

30 **[0005]** Patent Document 2 discloses a steel structure comprising 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, having a ferrite area fraction of 0% or more and 90% or less, a bainite area fraction of 5% or less (including 0%), a martensite and tempered martensite area fraction of 10% or more (including 100%), and a retained austenite area fraction of 2.0% or less (including 0%), wherein the standard deviation of the yield strength in the width direction is 30 MPa or less, and when sheared at a length of 1 m, the plate relates to a thin steel sheet with a maximum warpage of 10 mm or less. However, in the case of Patent Document 2, there is a problem that shape defects occur due to rapid cooling after annealing.

40 **[0006]** Therefore, to solve the aforementioned problems, it is necessary to develop an ultra-high-strength cold-rolled steel sheet with a tensile strength of 1470 MPa or more, which has an excellent shape as well as excellent bendability, spot weldability, and corrosion resistance.

[Prior Art Document]

45 **[0007]**

(Patent Document 1) Japanese Unexamined Patent Application Publication No. 2010-248565

(Patent Document 2) Japanese Unexamined Patent Application Publication No. 2020-019992

50 Disclosure of Invention

Technical Problem

55 **[0008]** An aspect of the present disclosure is to provide a cold-rolled steel sheet and a method for manufacturing the same.

[0009] An advantageous aspect of the present disclosure is to provide an ultra-high-strength cold-rolled steel sheet with a tensile strength of 1470 MPa or more, which has an excellent shape as well as excellent bendability, spot

weldability, and corrosion resistance, and a method for manufacturing the same.

Solution to Problem

5 **[0010]** An embodiment of the present disclosure provides a cold-rolled steel sheet comprising, by weight %, carbon (C): 0.150-0.350%, silicon (Si): 0.0050-0.70%, manganese (Mn): 0.30-2.50%, chromium (Cr): 0.0050-0.60%, molybdenum (Mo): 0.0030-0.50%, phosphorus (P): 0.030% or less (excluding 0%), and sulfur (S): 0.0070% or less (excluding 0%), with the remainder being Fe and other unavoidable impurities, wherein the steel sheet is divided into a central portion and a surface layer portion formed on the outer side of the central portion in the thickness direction, and the surface roughness (Rsk) of the surface layer portion is -0.65 to 0.65.

(Here, the surface layer portion refers to a region up to 20 μm from the surface of the steel material in the thickness direction).

[0011] In the cold-rolled steel sheet, the product of the surface roughness (Rsk) and Pc of the surface layer portion may be -150 or more.

15 **[0012]** In the cold-rolled steel sheet, the absolute value of the product of the surface roughness (Rsk) and the bendability (R/t) of the surface layer portion may be 2.4 or less.

[0013] Another embodiment of the present disclosure provides a cold-rolled steel sheet comprising, by weight %, carbon (C): 0.150-0.350%, silicon (Si): 0.0050-0.70%, manganese (Mn): 0.30-2.50%, chromium (Cr): 0.0050-0.60%, molybdenum (Mo): 0.0030-0.50%, phosphorus (P): 0.030% or less (excluding 0%), and sulfur (S): 0.0070% or less (excluding 0%), with the remainder being Fe and other unavoidable impurities, wherein the steel sheet is divided into a central portion and a surface layer portion formed on the outer side of the central portion in the thickness direction. When measured by EBSD with the number fraction of the region where the KAM value is 0-5.0° set to 100%, the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion is 30% or less (excluding 0%), the number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion is 55% or less (excluding 0%), and the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion and the number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion have a relationship of $m < n$.

(Here, the surface layer portion refers to a region up to 20 μm from the surface of the steel material in the thickness direction, and KAM (Kernel Average Misorientation) refers to the misorientation.)

30 **[0014]** The cold-rolled steel sheet may further include one or more selected from boron (B): 0.00050-0.0050%, aluminum (Al): 0.010-0.10%, niobium (Nb): 0.010-0.010%, titanium (Ti): 0.0050-0.080%, and nitrogen (N): 0.010% or less (excluding 0%).

[0015] The cold-rolled steel sheet may satisfy the following Formulas 1 to 4.

35 [Formula 1] $X = C + 0.03Si + 0.02Mn : 0.24-0.40$

$Y = (Cr + 0.8C + 0.07(Si+Mn) - 0.1Mo - 50B - 70P - 30S) \times 100 + 100 : 30-120$ [Formula 2]

40 [Formula 3] $Y/X = 125-375$

$Z = 48.8 + 49\log C + 35.1Mn + 25.9Si + 76.5Cr + 105.9Mo + 1325Nb + 10000B : 55-250$ [Formula 4]

45 (Here, the content of each alloying element in Formulas 1 to 4 is in weight %.)

[0016] The number fraction (m) of the region where the KAM value is 0-1.0° in the central portion and the number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion may have a relationship of $m < n$.

[0017] The microstructure of the central portion may include, by area %, a total fraction (a) of one or more of ferrite and bainite: 5% or less (excluding 0%), with the remainder being one or more of martensite and tempered martensite.

50 The microstructure of the surface layer portion may include, by area %, a total fraction (b) of one or more of ferrite and bainite: 10% or less (excluding 0%), with the remainder being one or more of martensite and tempered martensite.

[0018] The a and b may have a relationship of $0.1 < a/b < 0.8$.

[0019] The average size of carbides within the laths of the tempered martensite may be 200 nm or less (excluding 0 nm).

55 **[0020]** In the cold-rolled steel sheet, the maximum size of MnS inclusions may be 50 μm or less (excluding 0 μm).

[0021] The residual stress of the surface layer portion may be -30 MPa or less.

[0022] The cold-rolled steel sheet may have a yield strength of 1050-1700 MPa, a tensile strength of 1470-1900 MPa, a yield ratio of 0.65-0.95, an elongation of 4-10%, a bendability (R/t) of 4 or less, and a maximum 3-point

bending angle of 40° or more.

[0023] In a cold-rolled steel sheet according to another embodiment of the present disclosure, the product of the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion and the elongation is 80-210%², and the ratio of the yield strength (YS) to the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion (YS/m) may be 45 MPa/% or more.

[0024] After resistance spot welding, the cold-rolled steel sheet may have a weld hardness of 650 Hv or less and a cross-tension strength (CTS) of the weld of 4.5 kN or more.

[0025] When the cold-rolled steel sheet is subjected to a bare sheet corrosion resistance test for 30 cycles, the number of holes with a diameter of 3 mm or more may be zero.

[0026] Yet another embodiment of the present disclosure provides a method for manufacturing a cold-rolled steel sheet, the method comprising: a step of heating a slab comprising, by weight %, carbon (C): 0.150-0.350%, silicon (Si): 0.0050-0.70%, manganese (Mn): 0.30-2.50%, chromium (Cr): 0.0050-0.60%, molybdenum (Mo): 0.0030-0.50%, phosphorus (P): 0.030% or less (excluding 0%), and sulfur (S): 0.0070% or less (excluding 0%), with the remainder being Fe and other unavoidable impurities; a step of finish hot rolling the heated slab to obtain a hot-rolled steel sheet; a step of coiling the hot-rolled steel sheet; a step of cold rolling the coiled hot-rolled steel sheet at a cold reduction ratio of 35-70% using a roll with a surface roughness (Ra) of 2.5 μm or more to obtain a cold-rolled steel sheet; a step of continuously annealing the cold-rolled steel sheet; a step of first cooling the continuously annealed cold-rolled steel sheet to a first cooling end temperature (T1) of 660°C to Ac3; a step of second cooling the first-cooled cold-rolled steel sheet to a second cooling end temperature (T2) of 50-300°C; a step of reheating the second-cooled cold-rolled steel sheet and then over-aging it at an over-aging treatment temperature (H) of 100-250°C; a step of skin pass rolling the over-aged cold-rolled steel sheet with a rolling force of 500-1000 tons; and a step of tension leveling the skin-pass-rolled cold-rolled steel sheet at an elongation of 0.05-0.65%.

[0027] The slab may further include one or more selected from boron (B): 0.00050-0.0050%, aluminum (Al): 0.010-0.10%, niobium (Nb): 0.0010-0.10%, titanium (Ti): 0.0050-0.080%, and nitrogen (N): 0.010% or less (excluding 0%).

[0028] The slab may satisfy the following Formulas 1 to 4.

$$[\text{Formula 1}] \quad X = C + 0.03\text{Si} + 0.02\text{Mn} : 0.24-0.40$$

$$Y = (\text{Cr} + 0.8C + 0.07(\text{Si} + \text{Mn}) - 0.1\text{Mo} - 50\text{B} - 70\text{P} - 30\text{S})X100 + 100 : 30-120 \quad [\text{Formula 2}]$$

$$[\text{Formula 3}] \quad Y/X = 125-375$$

$$Z = 48.8 + 49\log C + 35.1\text{Mn} + 25.9\text{Si} + 76.5\text{Cr} + 105.9\text{Mo} + 1325\text{Nb} + 10000\text{B} : 55-250 \quad [\text{Formula 4}]$$

(Here, the content of each alloying element in Formulas 1 to 4 is in weight %.)

[0029] The slab heating may be performed at 1100-1300°C.

[0030] The finish hot rolling may be performed at Ar3 to Ar3+120°C.

[0031] The coiling may be performed at Ms to 700°C.

[0032] The continuous annealing may be performed at Ac3 to Ac3+100°C for 30-230 seconds.

[0033] The first cooling may be performed at an average cooling rate of 1-6°C/s.

[0034] The second cooling may be performed at an average cooling rate of 30-300°C/s.

[0035] During the first and second cooling, the difference between the first cooling end temperature (T1) and the second cooling end temperature (T2), T1-T2, may be controlled to be 650°C or less.

[0036] The over-aging treatment may be performed for 5-12 minutes.

[0037] During the second cooling and over-aging treatment, the difference between the over-aging treatment temperature (H) and the second cooling end temperature (T2), H-T2, may be controlled to be 30°C or more.

Advantageous Effects of Invention

[0038] According to an aspect of the present disclosure, a cold-rolled steel sheet and a method for manufacturing the same can be provided.

[0039] According to an advantageous aspect of the present disclosure, it is possible to provide an ultra-high-strength cold-rolled steel sheet with a tensile strength of 1470 MPa or more, which has an excellent shape as well as excellent bendability, spot weldability, and corrosion resistance, and a method for manufacturing the same.

Brief Description of Drawings

[0040]

FIG. 1 is a TEM photograph of Invention Example 6.
 FIG. 2 is a TEM photograph of Comparative Example 12.
 FIG. 3 is a photograph of Invention Example 6 after a bare sheet corrosion resistance evaluation.
 FIG. 4 is a photograph of Comparative Example 3 after a bare sheet corrosion resistance evaluation.

Best Mode for the Invention

[0041] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. The singular forms used herein are intended to include the plural forms as well, unless the context clearly indicates otherwise. The term "comprising" as used in the specification specifies the presence of stated features, regions, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of one or more other features, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0042] Unless otherwise defined, all terms, including technical and scientific terms, used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Terms defined in commonly used dictionaries are to be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure, and are not to be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0043] 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 compositions described below refer to weight % unless otherwise specified.

Carbon (C): 0.150-0.350%

[0044] C is an interstitial solid solution element and is the most effective and important element for improving the strength of steel. Furthermore, it is an element that must be added to secure the strength of martensitic steel. If the content of C is less than 0.150%, it may be difficult to obtain the yield ratio and tensile strength targeted in the present disclosure. If the content of C exceeds 0.350%, the strength increases sharply, which may degrade the elongation. In addition, weldability may be degraded. Therefore, it is advantageous for the content of C to be in the range of 0.150-0.350%. The lower limit of the C content is more preferably 0.170%, even more preferably 0.190%, and most preferably 0.20%. The upper limit of the C content is more preferably 0.330%, even more preferably 0.30%, and most preferably 0.270%.

Silicon (Si): 0.0050-0.70%

[0045] Si serves to suppress the formation of carbides and control the size of carbides in the reheating and over-aging treatment steps performed after continuous annealing and cooling. If the content of Si is less than 0.0050%, it may be difficult to sufficiently obtain the above-described effects. If the content of Si exceeds 0.70%, there is a concern that ferrite may be excessively formed after continuous annealing and cooling, thereby weakening the strength of the steel. In addition, Si is an element that increases specific resistance, which may degrade resistance spot weldability. Therefore, it is advantageous for the content of Si to be in the range of 0.0050-0.70%. The lower limit of the Si content is more preferably 0.010%, even more preferably 0.030%, and most preferably 0.050%. The upper limit of the Si content is more preferably 0.60% and even more preferably 0.50%.

Manganese (Mn): 0.30-2.50%

[0046] Mn is an element added to secure strength. If the content of Mn is less than 0.30%, martensite is not formed if the cooling rate is not sufficiently fast during cooling after continuous annealing due to low hardenability, making it difficult to secure the level of strength targeted in the present disclosure. If the content of Mn exceeds 2.50%, the Ms temperature is lowered during cooling after continuous annealing, which lowers the temperature at which cooling must end, resulting in a poor shape of the steel sheet. In addition, it is difficult to secure a martensitic structure. Furthermore, during the steelmaking/continuous casting process, Mn-based segregation bands occur in the longitudinal direction of the slab, degrading bendability. That is, as manganese segregates in the thickness direction and an Mn band is formed in the slab, cracks occur during continuous casting, and the occurrence of defects during the rolling process

increases. Therefore, it is advantageous for the content of Mn to be in the range of 0.30-2.50%. The lower limit of the Mn content is more preferably 0.50%, even more preferably 1.0%, and most preferably 1.50%. The upper limit of the Mn content is more preferably 2.30%.

5 Chromium (Cr): 0.0050-0.60%

[0047] Cr is an element that facilitates securing a low-temperature transformation structure by suppressing ferrite transformation. In addition, when utilizing a continuous annealing process where slow cooling exists, as in the present disclosure, it has the advantage of suppressing ferrite formation. If the content of Cr is less than 0.0050%, martensite is not formed if the cooling rate is not sufficiently fast during cooling after continuous annealing due to low hardenability, making it difficult to secure the level of strength targeted in the present disclosure. If the content of Cr exceeds 0.60%, delayed fracture resistance may be deteriorated, and carbides such as CrC may be formed, which degrades bendability and increases manufacturing costs due to an excessive amount of alloy addition. Therefore, it is advantageous for the content of Cr to be in the range of 0.0050-0.60%. 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): 0.0030-0.50%

[0048] Mo is an element that exhibits the effect of improving the hardenability of steel, the effect of generating Mo-based fine carbides that become hydrogen trap sites, and the effect of improving delayed fracture resistance characteristics by refining martensite. If the content of Mo is less than 0.0030%, it may be difficult to sufficiently obtain the above-described effects. If the content of Mo exceeds 0.50%, the above-described effects do not significantly increase compared to the cost increase due to the addition of an expensive alloying element. Therefore, it is advantageous for the content of Mo to be in the range of 0.0030-0.50%. The lower limit of the Mo content is more preferably 0.0050%. The upper limit of the Mo content is more preferably 0.40%.

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

[0049] P is an impurity element contained in steel, and if the content of P exceeds 0.030%, weldability may be deteriorated and embrittlement of the steel may occur. On the other hand, although it is advantageous for P not to be included in the steel as much as possible, 0% is excluded in consideration of cases where it is unavoidably included in the manufacturing process. Therefore, it is advantageous for the content of P to be 0.030% or less (excluding 0%). The content of P is more preferably 0.0250% or less.

35 Sulfur (S): 0.0070% or less (excluding 0%)

[0050] S, like P, is an impurity element contained in steel. If the content of S exceeds 0.0070%, ductility and weldability may be impaired, and a large amount of MnS precipitates may form, degrading bendability. On the other hand, although it is advantageous for S not to be included in the steel as much as possible, 0% is excluded in consideration of cases where it is unavoidably included in the manufacturing process. Therefore, it is advantageous for the content of S to be 0.0070% or less (excluding 0%). The content of S is more preferably 0.0050% or less, even more preferably 0.0030% or less, and most preferably 0.0020% or less.

[0051] The remaining component is iron (Fe). However, in a normal manufacturing process, unintended impurities from raw materials or the surrounding environment may be unavoidably incorporated, so these cannot be excluded. Since these impurities are known to any person skilled in the art of the normal manufacturing process, all of their details are not specifically mentioned in this specification.

[0052] The cold-rolled steel sheet according to an embodiment of the present disclosure may further include one or more of Boron (B): 0.00050-0.0050%, Aluminum (Al): 0.010-0.10%, Niobium (Nb): 0.0010-0.10%, Titanium (Ti): 0.0050-0.080%, and Nitrogen (N): 0.010% or less (excluding 0%).

50 Boron (B): 0.00050-0.0050%

[0053] B is an element that suppresses ferrite formation, and accordingly, in the present disclosure, it has the advantage of suppressing the formation of ferrite during cooling after continuous annealing. If the content of B is less than 0.00050%, there is no hardenability effect at all, making it impossible to secure the strength targeted in the present disclosure, and there is a problem that ferrite is excessively formed in the surface layer portion, degrading bendability. If the content of B exceeds 0.0050%, ductility may be significantly reduced. Therefore, it is advantageous for the content of B to be in the range of 0.00050-0.0050%. The lower limit of the B content is more preferably

0.00070%. The upper limit of the B content is more preferably 0.0040%.

Aluminum (Al): 0.010-0.10%

[0054] Al can be added to remove oxygen in molten steel. If the content of Al is less than 0.010%, deoxidation is not sufficiently achieved, which impairs the cleanliness of the steel. If the content of Al exceeds 0.10%, the castability of the slab deteriorates, and the temperature required for single-phase region heating during continuous annealing increases, which may cause production and equipment problems. Therefore, it is advantageous for the content of Al to be in the range of 0.010-0.10%. The upper limit of the Al content is more preferably 0.0750%.

Niobium (Nb): 0.0010-0.10%

[0055] Nb is an element that segregates at austenite grain boundaries to suppress the coarsening of austenite crystal grains during the continuous annealing process, and forms fine precipitates to contribute to strength improvement. If the content of Nb is less than 0.0010%, the effects of austenite crystal grain refinement and precipitation strengthening cannot be sufficiently obtained. If the content of Nb exceeds 0.10%, the precipitation of coarse carbonitrides increases, and there is a concern that the strength and elongation may be lowered due to a decrease in the amount of carbon in the steel. In addition, there are problems of decreased workability of the base material and increased manufacturing costs. Therefore, it is advantageous for the content of Nb to be in the range of 0.0010-0.10%. The lower limit of the Nb content is more preferably 0.0030%. The upper limit of the Nb content is more preferably 0.090%.

Titanium (Ti): 0.0050-0.080%

[0056] Ti is a nitride-forming element that scavenges solute N by precipitating it as TiN. If the content of Ti is less than 0.0050%, it is not only difficult to obtain a strength-increasing effect, but also the effect of scavenging solute N is reduced, which may cause cracks during continuous casting as a large amount of AlN is formed. If the content of Ti exceeds 0.080%, the strength of martensite may be reduced due to the precipitation of additional carbides in addition to the removal of solute N, and the hole expandability and bendability may be impaired by the formation of excessive carbonitrides such as TiC and TiN. Therefore, it is advantageous for the content of Ti to be in the range of 0.0050-0.080%. The lower limit of the Ti content is more preferably 0.010%. The upper limit of the Ti content is more preferably 0.0060%, even more preferably 0.0050%, and still more preferably 0.0040%.

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

[0057] N is an impurity element, and if its content exceeds 0.010%, the risk of crack formation during continuous casting is greatly increased due to the formation of AlN and the like. Although it is advantageous for the content of N not to be included in the steel as much as possible, 0% is excluded in consideration of cases where it is unavoidably included in the manufacturing process. Therefore, it is advantageous for the content of N to be in the range of 0.010% or less (excluding 0%). The content of N is more preferably 0.0080% or less, and even more preferably 0.0060% or less.

[0058] The cold-rolled steel sheet according to an embodiment of the present disclosure may satisfy the above-described alloy composition and, at the same time, satisfy the following Formulas 1 to 4.

$$[\text{Formula 1}] \quad X = C + 0.03Si + 0.02Mn : 0.24-0.40$$

[0059] Formula 1 is a component relational expression that is closely related to the weld hardness and the spot welding cross-tension strength (CTS). If the value of X is less than 0.24, it is difficult to sufficiently secure the target strength due to low hardenability. If the value of X exceeds 0.40, the weld hardness becomes excessively high, increasing the risk of brittle fracture, and as a result, the cross-tension strength is lowered, which may degrade crash safety. Therefore, it is advantageous for the value of X to be in the range of 0.24-0.40. The lower limit of the X value is more preferably 0.25. The upper limit of the X value is more preferably 0.39.

$$Y = (Cr + 0.8C + 0.07(Si+Mn) - 0.1Mo - 50B - 70P - 30S)X100 + 100 : 30-120$$

[Formula 2]

[0060] Formula 2 is a component relational expression related to strength and corrosion resistance. If the value of Y is less than 30, it is difficult to secure sufficient strength because the target microstructure of the present disclosure

cannot be obtained due to insufficient hardenability. If the value of Y exceeds 120, there is a problem that not only the manufacturing cost increases, but also the corrosion resistance, such as perforation corrosion, deteriorates. Therefore, it is advantageous for the value of Y to be in the range of 30-120. The lower limit of the Y value is more preferably 40. The upper limit of the Y value is more preferably 110.

$$[\text{Formula 3}] \quad Y/X = 125-375$$

[0061] Formula 3 is a component relational expression for simultaneously securing spot weldability and corrosion resistance. If the value of Y/X is less than 125, spot weldability may be degraded. If the value of Y/X exceeds 375, corrosion resistance, such as perforation corrosion, may be degraded. Therefore, it is advantageous for the value of Y/X to be in the range of 125-375. The lower limit of the Y/X value is more preferably 135. The upper limit of the Y/X value is more preferably 350.

$$Z = 48.8 + 49\log C + 35.1\text{Mn} + 25.9\text{Si} + 76.5\text{Cr} + 105.9\text{Mo} + 1325\text{Nb} + 10000\text{B}; 55-250 \quad [\text{Formula 4}]$$

[0062] Formula 4 is a component relational expression for securing hardenability. If the value of Z is less than 55, soft ferrite and bainite structures are transformed during cooling, making it difficult to secure the target strength. If the value of X exceeds 250, the strength becomes excessively high, making it difficult to secure the target elongation, which may cause processing cracks during forming. Therefore, it is advantageous for the value of X to be in the range of 55-250. The lower limit of the X value is more preferably 60. The upper limit of the X value is more preferably 240.

[0063] The cold-rolled steel sheet according to an embodiment of the present disclosure may be divided into a central portion and a surface layer portion formed on the outer side of the central portion in the thickness direction. Meanwhile, the depth of the surface layer portion may be changed according to the thickness of the steel sheet, and thus is not particularly limited, but as an example, the surface layer portion may be a region up to 20 μm from the surface of the steel sheet in the thickness direction.

[0064] In the cold-rolled steel sheet according to an embodiment of the present disclosure, it is advantageous that the surface roughness (Rsk) of the surface layer portion is -0.65 to 0.65. The surface roughness (Rsk (Skewness)) is one of several factors of surface roughness related to the asymmetry of sharp protruding parts. The closer the value of the surface roughness (Rsk) is to 0 or the more positive it is, the more advantageous it is for securing bendability. As the negative value of the surface roughness (Rsk) increases, the valleys on the flat surface deepen, causing stress concentration in these areas, which increases the sensitivity to crack formation and, as a result, degrades the bendability. If the surface roughness (Rsk) is less than -0.65 or exceeds 0.65, the bendability may be degraded. Therefore, it is advantageous for the surface roughness (Rsk) to be in the range of -0.65 to 0.65. The lower limit of the surface roughness (Rsk) is more preferably -0.6, even more preferably -0.5, and most preferably -0.4. The upper limit of the surface roughness (Rsk) is more preferably 0.6, even more preferably 0.4, and most preferably 0.2.

[0065] In the cold-rolled steel sheet according to an embodiment of the present disclosure, the product of the surface roughness (Rsk) and Pc of the surface layer portion may be -150 or more. The Pc is a factor indicating the number of peaks that completely deviate from the bandwidth within a unit length. The higher the product of Rsk and Pc, the more advantageous it is for bendability. That is, in the present disclosure, bendability can be improved by controlling the product of the surface roughness (Rsk) and Pc of the surface layer portion to a level of -150 or more. Therefore, it is advantageous for the product of the surface roughness (Rsk) and Pc of the surface layer portion to be -150 or more. The product of the surface roughness (Rsk) and Pc of the surface layer portion is more preferably -140 or more, even more preferably -130 or more, and most preferably -120 or more. On the other hand, in the present disclosure, the higher the product of Rsk and Pc, the more advantageous it is, so its upper limit is not particularly limited. However, as an example, the upper limit of the product of the surface roughness (Rsk) and Pc of the surface layer portion may be +60.

[0066] In the cold-rolled steel sheet according to an embodiment of the present disclosure, the absolute value of the product of the surface roughness (Rsk) and the bendability (R/t) of the surface layer portion may be 2.4 or less.

[0067] Hereinafter, a cold-rolled steel sheet according to another embodiment of the present disclosure will be described.

[0068] The cold-rolled steel sheet according to another embodiment of the present disclosure may satisfy the same alloy composition as the cold-rolled steel sheet according to the above-described one embodiment. In addition, it may satisfy the above-described Formulas 1 to 4.

[0069] The cold-rolled steel sheet according to another embodiment of the present disclosure may also be divided into a central portion and a surface layer portion formed on the outer side of the central portion in the thickness direction. Meanwhile, the depth of the surface layer portion may be changed according to the thickness of the steel sheet, and thus is not particularly limited, but as an example, the surface layer portion may be a region up to 20 μm

from the surface of the steel sheet in the thickness direction.

[0070] In the cold-rolled steel sheet according to another embodiment of the present disclosure, when measured by EBSD with the number fraction of the region where the KAM value is 0-5.0° set to 100%, it is advantageous that the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion is 30% or less (excluding 0%).

The dislocation density within the crystal grains can be evaluated by the KAM (Kernel Average Misorientation) value. KAM means misorientation, and more specifically, the KAM value is the average value of the crystal rotation amount (crystal misorientation) between the target measurement point and its surrounding measurement points. A larger value means that more strain exists in the crystal. The present inventors have investigated the relationship between the KAM value and the microstructure and confirmed that a difference in physical properties occurs depending on the number fraction of the region where the KAM value is 0-1.0° in the central portion. In the present disclosure, in order to secure the target physical properties, it is advantageous to control the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion to a range of 30% or less (excluding 0%). If the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion exceeds 30%, it may be difficult to secure the target tensile strength because it contains a large amount of a structure with little strain. The number fraction of the region where the KAM value is 0-1.0° in the central portion is more preferably 29% or less.

[0071] In the cold-rolled steel sheet according to another embodiment of the present disclosure, when measured by EBSD with the number fraction of the region where the KAM value is 0-5.0° set to 100%, the number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion may be 55% or less (excluding 0%). If the number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion exceeds 55%, it may be difficult to secure the target tensile strength because it contains a large amount of a structure with little strain. The number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion is more preferably 50% or less.

[0072] In the cold-rolled steel sheet according to another embodiment of the present disclosure, the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion and the number fraction (n) of the region where the KAM value is 0-1.0° in the surface layer portion may have a relationship of $m < n$. If m is greater than or equal to n, it may be difficult to secure the target strength.

[0073] Meanwhile, in the cold-rolled steel sheet according to the one embodiment and the other embodiment, the microstructure of the central portion includes, by area %, a sum (a) of one or more of ferrite and bainite: 5% or less (excluding 0%), with the remainder being one or more of martensite and tempered martensite, and the microstructure of the surface layer portion may include, by area %, a sum (b) of one or more of ferrite and bainite: 10% or less (excluding 0%), with the remainder being one or more of martensite and tempered martensite.

[0074] It is advantageous that the main phase of the central portion microstructure includes one or more of martensite and tempered martensite. The martensite and tempered martensite are very advantageous structures for securing the strength, hole expandability, bendability, and weldability targeted by the present disclosure. However, one or more of ferrite and bainite may be unavoidably formed during the manufacturing process, and if the total fraction (a) of one or more of ferrite and bainite exceeds 5%, it may be difficult to secure the physical properties desired by the present disclosure. Therefore, it is advantageous for the total fraction (a) of one or more of ferrite and bainite to be 5% or less, and more preferably 3% or less. In the present disclosure, the lower limit of the total fraction (a) of one or more of ferrite and bainite is not particularly limited, but may be 0.5% as an example.

[0075] It is advantageous that the main phase of the surface layer microstructure includes one or more of martensite and tempered martensite. In addition, it is advantageous that the total fraction (b) of one or more of ferrite and bainite is 10% or less (excluding 0%). Since the ferrite and bainite are softer than martensite and tempered martensite, bendability can be further improved by forming an appropriate level of ferrite and bainite in the surface layer portion. If the total fraction of one or more of ferrite and bainite exceeds 10%, bendability may be degraded. Therefore, it is advantageous for the total fraction (b) of one or more of ferrite and bainite to be 10% or less, and more preferably 7% or less. In the present disclosure, the lower limit of the total fraction (b) of one or more of ferrite and bainite is not particularly limited, but may be 0.5% as an example.

[0076] The a and b may have a relationship of $0.1 < a/b < 0.8$. If a/b is 0.1 or less, bendability may be degraded. If a/b is 0.8 or more, it may be difficult to secure the target strength.

[0077] The average size of carbides within the laths of the tempered martensite may be 200 nm or less (excluding 0 nm). If the average carbide size exceeds 200 nm, bendability may be degraded. The average carbide size is more preferably 150 nm or less. In the present disclosure, the smaller the average carbide size, the more advantageous it is, so its lower limit is not particularly limited. However, the lower limit of the average carbide size may be 10 nm as an example. Meanwhile, the carbide may be, for example, one or more of a carbide containing Fe and Mn, a carbide containing Mn and Cr, and a carbide containing Fe, Mn, Cr, and Mo.

[0078] In the cold-rolled steel sheet according to the one embodiment and the other embodiment, the maximum size of MnS inclusions may be 50 μm or less (excluding 0 μm). If the maximum size of MnS inclusions exceeds 50 μm , bendability and hydrogen embrittlement resistance may be significantly degraded. The maximum size of MnS inclusions is more preferably 40 μm or less, and even more preferably 30 μm or less. Meanwhile, in the present disclosure,

the lower limit of the maximum size of MnS inclusions is not particularly limited. However, the lower limit of the maximum size of MnS inclusions may be 20 μm as an example.

[0079] In the cold-rolled steel sheet according to the one embodiment and the other embodiment, the residual stress of the surface layer portion may be -30 MPa or less. If the residual stress of the surface layer portion exceeds -30 MPa, bendability and hydrogen embrittlement resistance may be degraded. Therefore, it is advantageous for the residual stress of the surface layer portion to be -30 MPa or less. The residual stress of the surface layer portion is more preferably -40 MPa or less, and even more preferably -50 MPa or less. Meanwhile, in the present disclosure, the lower the residual stress of the surface layer portion, the more advantageous it is, so its lower limit is not particularly limited. However, as an example, the lower limit of the residual stress of the surface layer portion may be -300 MPa.

[0080] The cold-rolled steel sheet according to the one embodiment and the other embodiment may have a yield strength of 1050-1700 MPa, a tensile strength of 1470-1900 MPa, a yield ratio of 0.65-0.95, an elongation of 4-10%, a bendability (R/t) of 4 or less, a maximum 3-point bending angle of 40° or more, and a surface layer residual stress of -30 MPa or less. The lower limit of the yield ratio is more preferably 0.70, and even more preferably 0.75. The lower limit of the elongation is more preferably 5%, and even more preferably 6%. The bendability is more preferably 3.5 or less, and even more preferably 3.0 or less. In the present disclosure, the lower the bendability, the more advantageous it is, so its lower limit is not particularly limited, but as an example, the lower limit of the bendability may be 2.5. The higher the residual stress (MPa) of the surface layer portion, the more tensile stress is applied, which may be disadvantageous for securing bendability and hydrogen embrittlement resistance.

[0081] In the cold-rolled steel sheet according to the one embodiment and the other embodiment, when the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion decreases, the elongation tends to decrease, but the decrease in elongation is prevented by controlling the manufacturing process, particularly the cooling rate and the elongation during tension leveling. Accordingly, the product of the elongation and the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion may be 80-210%². In addition, in the cold-rolled steel sheet according to the one embodiment and the other embodiment, when the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion increases, the yield strength tends to decrease, but a high yield ratio can be secured by controlling the alloy composition or the cooling rate and the reheating/over-aging treatment process during the manufacturing process. Accordingly, the ratio of the yield strength (YS) to the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion (YS/m) may be 45 MPa/% or more. More preferably, the ratio of the yield strength (YS) to the number fraction (m) of the region where the KAM value is 0-1.0° in the central portion (YS/m) may be 45-68 MPa/%.

[0082] In the cold-rolled steel sheet according to the one embodiment and the other embodiment, after resistance spot welding, the hardness of the weld may be 650 Hv or less, and the cross-tension strength (CTS) of the weld may be 4.5 kN or more. In the present disclosure, the hardness of the weld is not particularly limited, but as an example, the lower limit of the hardness of the weld after resistance spot welding may be 440 Hv. In addition, in the present disclosure, the upper limit of the cross-tension strength (CTS) of the weld after resistance spot welding is not particularly limited, but as an example, the upper limit of the cross-tension strength (CTS) of the weld may be 12 kN.

[0083] In the cold-rolled steel sheet according to the one embodiment and the other embodiment, when a bare sheet corrosion resistance test is performed for 30 cycles, the number of holes with a diameter of 3 mm or more may be 0. One cycle of the bare sheet corrosion resistance evaluation may be performed, for example, by Slat Spray (5% NaCl, neutral, 35°C, salt spray amount: 1-2 mL/hr, 6 hr) -> Drying (50°C, 20-40% RH, 3 hr) -> Wetting (50°C, 95% RH, 14 hr) -> Cold air blasting (50% RH, 1 hr).

[0084] In the cold-rolled steel sheet according to the one embodiment and the other embodiment, a coating layer may be formed on at least one surface. In the present disclosure, the type of the coating layer is not particularly limited, but as an example, the coating layer may be an electrogalvanized zinc layer.

[0085] The cold-rolled steel sheet according to the one embodiment and the other embodiment may have a thickness of 0.6-2.5 mm. The lower limit of the thickness of the cold-rolled steel sheet is more preferably 0.7 mm, and even more preferably 0.8 mm. The upper limit of the thickness of the cold-rolled steel sheet is more preferably 2.4 mm, and even more preferably 2.3 mm.

[0086] Hereinafter, a method for manufacturing a cold-rolled steel sheet according to an embodiment of the present disclosure will be described.

[0087] First, a slab satisfying the above-described alloy composition is heated. The slab may satisfy the above-described Formulas 1 to 4. The slab heating process is performed to smoothly carry out the subsequent hot rolling process and to sufficiently obtain the target physical properties of the steel sheet. The heating of the slab may be performed at 1100-1300°C. If the slab heating temperature is less than 1100°C, a problem arises in that the hot rolling load increases sharply. If the slab heating temperature exceeds 1300°C, the amount of surface scale increases, thereby reducing the yield of the material. The lower limit of the slab heating temperature is more preferably 1110°C, even 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.

[0088] Thereafter, the heated slab is finish hot rolled to obtain a hot-rolled steel sheet. The finish hot rolling may be performed at Ar3 to Ar3+120°C. If the finish hot rolling temperature is less than Ar3, two-phase region rolling of ferrite + austenite or ferrite region rolling is performed, resulting in a mixed grain structure, and sheet breakage may occur due to fluctuations in the hot rolling load. If the finish hot rolling temperature exceeds Ar3+120°C, a large amount of surface scale is generated, which may degrade the surface quality. The lower limit of the finish hot rolling temperature is more preferably Ar3+10°C, even more preferably Ar3+20°C, and most preferably Ar3+30°C. The upper limit of the finish hot rolling temperature is more preferably Ar3+110°C, even more preferably Ar3+100°C, and most preferably Ar3+90°C. Meanwhile, Ar3 refers to the temperature at which austenite begins to transform into ferrite during cooling, and can be obtained through the following Equation 1.

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

[0089] Thereafter, the hot-rolled steel sheet is coiled. The coiling may be performed at Ms to 700°C. If the coiling temperature exceeds 700°C, internal oxidation occurs on the surface of the steel sheet, making the microstructure formed in the surface layer portion non-uniform, and accordingly, the bendability may be degraded. Meanwhile, it is advantageous to manage the coiling temperature to be low in order to form the microstructure of the hot-rolled steel sheet as a single-phase structure rather than a composite structure as much as possible to secure material uniformity over the entire length and width. However, if the coiling temperature is less than Ms, the strength of the hot-rolled steel sheet becomes excessively high, which increases the rolling load during the subsequent cold rolling process, making actual production impossible. The lower limit of the coiling temperature is more preferably Ms+50°C. The upper limit of the coiling temperature is more preferably 690°C. The Ms refers to the temperature at which austenite begins to transform into martensite during cooling, and can be obtained through the following Equation 2.

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

[0090] Meanwhile, after the coiling, cooling can be performed through 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.

[0091] Thereafter, the coiled hot-rolled steel sheet is cold rolled at a cold reduction ratio of 35-70% using a roll with a surface roughness (Ra) of 2.5 μm or more to obtain a cold-rolled steel sheet. If the surface roughness (Ra) of the cold rolling roll is less than 2.5 μm, the negative value of the surface roughness (Rsk) of the steel sheet may become excessively large, leading to a decrease in bendability. In the present disclosure, the larger the surface roughness (Ra) of the cold rolling roll, the fewer deep grooves are created in the rolling direction, which is detrimental to bendability, so its upper limit is not particularly limited. The surface roughness (Ra) of the cold rolling roll is more preferably 3.0 μm or more, and since a larger surface roughness (Ra) of the cold rolling roll is more advantageous in the present disclosure, its upper limit is not particularly limited, but as an example, the upper limit of the surface roughness (Ra) of the cold rolling roll may be 6.5 μm. If the cold reduction ratio is less than 35%, it is not only difficult to secure the thickness desired in the present disclosure, but also austenite is generated during annealing heat treatment due to the residual crystal grains formed during hot rolling, which may affect the final physical properties. In addition, the negative value of the surface roughness (Rsk) may become excessively large, leading to a decrease in bendability. If the cold reduction ratio exceeds 70%, the reduction amount in the length and width directions may become non-uniform due to work hardening that occurs during cold rolling, which may cause material deviation in the steel sheet. In addition, it may be difficult to secure the thickness desired in the present disclosure due to the rolling load. The lower limit of the cold reduction ratio is more preferably 36%, even more preferably 37%, and most preferably 38%. The upper limit of the cold reduction ratio is more preferably 68%, even more preferably 66%, and most preferably 64%.

[0092] Thereafter, the cold-rolled steel sheet is continuously annealed. The continuous annealing may be performed at Ac3 to Ac3+100°C for 30-230 seconds. If the continuous annealing temperature is less than Ac3, a mixed grain structure may be formed as two-phase region annealing, rather than single-phase region annealing, occurs over the entire length of the steel sheet, making it difficult to secure the physical properties targeted by the present disclosure, and in particular, the hardness difference between phases becomes large, which may significantly degrade hole expandability. If the continuous annealing temperature exceeds Ac3+100°C, equipment trouble may occur due to an overload of the annealing furnace. The lower limit of the continuous annealing temperature is more preferably Ac3+5°C, even more preferably Ac3+10°C, and most preferably Ac3+15°C. The upper limit of the continuous annealing temperature is more preferably Ac3+95°C, even more preferably Ac3+90°C, and most preferably Ac3+85°C. Meanwhile, Ac3 refers to the temperature at which the transformation of ferrite to 100% austenite is completed during heating, and can be obtained through the following Equation 3.

$$Ac3(^{\circ}C) = 875 - 206C + 26.2Si - 25.0Mn - 12.3Cr + 9.12Mo + 50.2Nb + 148Ti - 131B$$

[Equation 3]

[0093] The continuous annealing may be performed for 30-230 seconds. If 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. If the continuous annealing time exceeds 230 seconds, there is a disadvantage in that the austenite size becomes coarse, making it difficult to secure strength and bendability. 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.

[0094] Thereafter, the continuously annealed cold-rolled steel sheet is first cooled to a first cooling end temperature (T1) of 660-Ac3°C. If the first cooling end temperature (T1) is less than 660°C, a large amount of soft ferrite and bainite, in addition to martensite, is formed during the cooling process, making the surface layer structure non-uniform, which may degrade bendability. If the first cooling end temperature (T1) exceeds Ac3, the temperature difference between the first cooling end temperature (T1) and the second cooling end temperature (T2) becomes severe, causing a rapid phase transformation, which may result in a poor product shape. The lower limit of the first cooling end temperature is more preferably 665°C. The upper limit of the first cooling end temperature is more preferably Ac3-10°C. The first cooling may be performed at an average cooling rate of 1-6°C/s. If the first average cooling rate is less than 1°C/s, ferrite is formed during cooling, making it impossible to secure the level of strength targeted by the present disclosure. If the first average cooling rate exceeds 6°C/s, the average cooling rate during the subsequent second cooling is lowered, and the fraction of other low-temperature transformation phases other than martensite increases, making it impossible to secure the level of strength targeted by the present disclosure. The lower limit of the first average cooling rate is more preferably 2°C/s. The upper limit of the first average cooling rate is more preferably 5°C/s.

[0095] Thereafter, the first-cooled cold-rolled steel sheet is second-cooled to a second cooling end temperature (T2) of 50-300°C. The second cooling is for securing one or more of martensite and tempered martensite, which are the main phases of the present disclosure. If the second cooling end temperature (T2) is less than 110°C, shape defects are caused by rapid phase transformation, and continuous production is difficult due to the strip's meandering problem. If the second cooling end temperature (T2) exceeds 300°C, it may be difficult to secure the strength targeted by the present disclosure. The lower limit of the second cooling end temperature is more preferably 115°C, even more preferably 120°C, and most preferably 130°C. The upper limit of the second cooling end temperature is more preferably 290°C, even more preferably 280°C, and most preferably 270°C. The second cooling may be performed at an average cooling rate of 30-300°C/s. If the second average cooling rate is less than 30°C/s, soft ferrite transformation occurs during cooling, making it difficult to secure the target strength. If the second average cooling rate exceeds 300°C/s, the product shape may become poor due to rapid phase transformation. The lower limit of the second 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 second average cooling rate is more preferably 290°C/s, even more preferably 280°C/s, and most preferably 270°C/s.

[0096] During the first and second cooling, the difference between the first cooling end temperature (T1) and the second cooling end temperature (T2), T1-T2, may be controlled to be 650°C or less. If T1-T2 exceeds 650°C, shape defects may occur. It is more preferable that T1-T2 is 600°C or less.

[0097] Thereafter, the second-cooled cold-rolled steel sheet is reheated and then over-aged at an over-aging treatment temperature (H) of 100-250°C. Through the reheating and over-aging treatment, the martensite obtained by the above-described quenching process can be transformed into tempered martensite to increase the yield strength. If the reheating temperature and the over-aging treatment temperature are less than 100°C, there is a disadvantage in that tempering is not sufficiently performed, resulting in low yield strength and an inability to secure sufficient toughness. If the reheating temperature and the over-aging treatment temperature exceed 250°C, there is a disadvantage in that bendability is degraded due to a large amount of precipitation and coarsening of carbides. The lower limit of the reheating temperature and the over-aging treatment temperature is more preferably 110°C, even more preferably 120°C, and most preferably 130°C. The upper limit of the reheating temperature and the over-aging treatment temperature is more preferably 245°C, even more preferably 240°C, and most preferably 235°C. The over-aging treatment may be performed for 5-12 minutes. If the over-aging treatment time is less than 5 minutes, tempering may not be sufficiently performed, resulting in a lower yield strength. If the over-aging treatment time exceeds 12 minutes, carbides may coarsen due to excessive tempering, which may degrade bendability. The lower limit of the over-aging 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 over-aging treatment time is more preferably 11.5 minutes, even more preferably 11 minutes, and most preferably 10.5 minutes.

[0098] During the second cooling and over-aging treatment, the difference between the over-aging treatment tem-

perature (H) and the second cooling end temperature (T2), H-T2, may be controlled to be 30°C or more. If H-T2 is less than 30°C, tempering may not be sufficiently performed, making it difficult to secure the target yield strength. It is more preferable that H-T2 is 50°C or more.

[0099] Thereafter, the over-aged cold-rolled steel sheet is skin pass rolled (SPM) with a rolling force of 500-1000 tons. The skin pass rolling enables control of the surface roughness (Rsk). If the rolling force during skin pass rolling is less than 500 tons, it is difficult to control the surface roughness (Rsk) due to the low load, and if it exceeds 1000 tons, the surface work hardening is severe, which may rather degrade the bendability. The lower limit of the rolling force during skin pass rolling is more preferably 550 tons, and even more preferably 600 tons. The upper limit of the rolling force during skin pass rolling is more preferably 950 tons, and even more preferably 900 tons.

[0100] Thereafter, the skin-pass-rolled cold-rolled steel sheet is tension leveled (T/L) at an elongation of 0.05-0.65%. The tension leveling is for correcting the shape of the steel sheet. If the elongation during tension leveling is less than 0.05%, shape correction may be difficult. If the elongation during tension leveling exceeds 0.65%, work hardening becomes severe, which may degrade bendability. The lower limit of the elongation during tension leveling is more preferably 0.10%, and even more preferably 0.15%. The upper limit of the elongation during tension leveling is more preferably 0.60%, and even more preferably 0.55%.

[0101] 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 further included. In the present disclosure, the method for forming the coating layer is not particularly limited, but as an example, an electro galvanizing method may be used.

Mode for Invention

[0102] Hereinafter, the present disclosure will be described in more detail through examples. However, the description of these examples is only for illustrating the practice of the present disclosure, and the present disclosure is not limited by the description of these examples. This is because the scope of the rights of the present disclosure is determined by the matters described in the claims and matters reasonably inferred therefrom.

(Example 1)

[0103] A slab having the alloy composition shown in Table 1 below was heated at 1200°C, and then the heated slab was finish hot rolled at 900°C to obtain a hot-rolled steel sheet, which was coiled at 450°C. Thereafter, it was cold rolled at the cold reduction ratio shown in Table 2 below to obtain a cold-rolled steel sheet. Thereafter, a cold-rolled steel sheet was manufactured by continuous annealing, first cooling, second cooling, reheating/over-aging, skin pass rolling, and tension leveling under the conditions shown in Tables 2 and 3 below. Meanwhile, the conditions shown in Tables 2 and 3 below were based on the surface temperature of the steel sheet.

[0104] For the cold-rolled steel sheet manufactured as described above, the microstructure, the number fraction of the region where the KAM value is 0-1.0°, the average size of carbides within the laths of tempered martensite, the maximum size of MnS inclusions, the surface roughness, the surface layer residual stress, and the mechanical properties were measured, and the results are shown in Tables 4 to 7 below.

[0105] The type and fraction of the microstructure were observed using a scanning electron microscope (SEM) and an optical microscope (OM) for the surface layer portion (at a position of 20 μm from the surface in the thickness direction) and the central portion (at a position of 1/4t, where t is the thickness of the steel sheet) of the steel sheet, and then the fraction of each phase was analyzed 20 times through image analysis to calculate the average value.

[0106] The number fraction of the region where the Kernel Average Misorientation (KAM) value is 0-1.0° was calculated by measuring 3 times (Confidence Index (CI) ≥ 0.3) at a magnification of 2000x using EBSD (Electron Backscatter Diffraction) for the surface layer portion (at a position of 20 μm from the surface in the thickness direction) and the central portion (at a position of 1/4t, where t is the thickness of the steel sheet) of the steel sheet, and then averaging the values. At this time, during the EBSD measurement, the number fraction of the region where the KAM value is 0-5.0° was considered to be 100%.

[0107] The average size of carbides within the laths of tempered martensite was calculated by preparing a thin film specimen, photographing it with a transmission electron microscope (TEM), and then averaging the values.

[0108] The maximum size of MnS inclusions was calculated by measuring 20 times at a magnification of 500x using an Electron Probe Micro Analyzer (EPMA) and then averaging the values.

[0109] The surface roughness (Rsk, Pc) was measured 10 times using a contact-type 2D roughness tester, and then the average value was calculated, excluding the maximum (Max) and minimum (Min) values.

[0110] The surface layer residual stress was measured 10 times using XRD (X-ray generator: 40kV, 30mA, Scan step: 0.0194°, Scan speed: 1.247°/min, Scan mode: 0D(continuous), Scan axis: 2θ/θ, Wavelength Kα₁: 0.154nm), and then the average value was calculated, excluding the maximum (Max) and minimum (Min) values.

[0111] The yield strength, tensile strength, yield ratio, and total elongation were measured by processing the cold-

rolled steel sheet into a JIS No. 5 standard specimen and then performing a tensile test under the condition of a test speed of 28 mm/min.

[0112] The bendability (R/t) was obtained by processing the cold-rolled steel sheet into a specimen with a width of 100 mm and a length of 30 mm, performing a 90° bending test at a test speed of 800 mm/min, checking for cracks in the bent portion using a stereoscopic microscope, and then dividing the minimum bending radius (R value of the die) at which no cracks occurred by the thickness (mm) of the specimen.

[0113] The maximum 3-point bending angle was calculated by measuring 5 times under VDA conditions (0.4R) and averaging the values.

[0114] The bare sheet corrosion resistance was measured by preparing a specimen with a width of 75 mm and a length of 150 mm, performing a corrosion test for 30 cycles, where 1 cycle consists of Slat Spray (5% NaCl, neutral, 35°C, salt spray amount: 1-2 mL/hr, 6 hr) → Drying (50°C, 20-40% RH, 3 hr) → Wetting (50°C, 95% RH, 14 hr) → Cold air blasting (50% RH, 1 hr), and then visually checking how many holes with a diameter of 3 mm or more occurred. It was evaluated as "not occurred" if the number of holes with a diameter of 3 mm or more was 0, and "occurred" if it was 1 or more.

[0115] For spot weldability, welding was performed under the conditions of Force: 4.95 KN, Welding time: 35 cycles, and Holding time: 1 cycle, with a welding current in the range of 4.0-7.0 kA. The welding current that satisfies the minimum nugget diameter ($4.25\sqrt{t}$, where t is the steel sheet thickness) was determined, and the hardness and cross-tension strength (CTS) of the spot weld made under these conditions were measured. In addition, the spot weld hardness was calculated by measuring the Vickers hardness (load: 500 gf) 10 times on the spot weld and averaging the values.

[Table 1]

Steel No .	Alloy Composition (wt%)													Y / X	Z
	C	Si	Mn	P	S	Al	Cr	Mo	Nb	Ti	B	N	X	Y	
1	0.23	0.09	1.95	0.010	0.0010.	0.030.	0.110	0.110	0.035	0.020	0.0025.	0.0040	0.27	57	211
2	0.29	0.15	1.75	0.011	0.0009	0.024	0.050	0.040	0.029	0.021	0.0025	0.0036	0.33	49	148
3	0.24	0.20	1.65	0.011	0.0014	0.034	0.090	0.100	0.025	0.015	0.0019	0.0037	0.28	49	175
4	0.26	0.05	2.10	0.008	0.0015	0.025	0.120	0.200	0.015	0.031	0.0021	0.0041	0.30	75	250
5	0.22	0.35	1.95	0.011	0.0008	0.015	0.050	0.060	0.005	0.014	0.0015	0.0035	0.27	51	189
6	0.46	0.15	2.10	0.010	0.0010	0.035	0.170	0.050	0.025	0.025	0.0019	0.0042	0.51	87	171
7	0.35	0.75	2.20	0.012	0.0012	0.035	0.350	0.090	0.025	0.025	0.0021	0.0041	0.42	85	202
8	0.24	0.25	2.20	0.010	0.0011	0.025	0.700	0.050	0.050	0.025	0.0035	0.0025	0.29	132	397
9	0.35	0.75	2.00	0.011	0.0018	0.021	0.010	0.006	0.025	0.021	0.0035	0.0024	0.41	48	117
10	0.14	0.01	0.40	0.012	0.0010	0.035	0.030	0.010	0.005	0.025	0.0020	0.0031	0.15	20	133
11	0.20	0.12	0.40	0.011	0.0009	0.035	0.001	0.001	0.015	0.015	0.0001	0.0051	0.21	40	190
12	0.24	0.12	1.71	0.010	0.0080	0.030	0.120	0.150	0.03	0.025	0.0020	0.0040	0.28	39	140
X = C + 0.03Si + 0.02Mn Y = (Cr + 0.8C + 0.07(Si+Mn) - 0.1Mo - 50B - 70P - 30S)X100 + 100 Z = 48.8 + 49logC + 35.1 Mn + 25.9Si + 76.5Cr + 105.9Mo + 1325Nb + 10000B Note: For Y/X, the value of X was calculated to two decimal places, and the value of Y was calculated to zero decimal places.															

EP 4 826 080 A1

[Table 2]

Category	Steel No.	Ar3 (°C)	Ms (°C)	Cold Red. Ratio (%)	Cold Roll Roug h. (μm)	Ac3 (°C)	Anneal Temp . (°C)	1st Cool End Temp . (T1) (°C)	1st Avg. Cool Rate (°C/ s)
Inv. Ex. 1	1	820	380	56	4.5	807	861	720	3
Inv. Ex. 2	2	809	362	56	4.5	794	835	745	3
Inv. Ex. 3	3	823	385	56	4.5	809	867	715	3
Inv. Ex. 4	4	815	363	56	4.5	801	852	731	3
Inv. Ex. 5	5	832	383	56	4.5	820	860	732	3
Comp . Ex. 1	6	781	278	56	4.5	762	834	730	3
Comp . Ex. 2	7	826	312	56	4.5	810	845	725	3
Comp . Ex. 3	8	823	361	56	4.5	810	856	736	3
Comp . Ex. 4	9	824	325	56	4.5	808	847	715	3
Comp . Ex. 5	10	834	468	56	4.5	824	849	711	3
Comp . Ex. 6	11	825	442	56	4.5	813	842	715	3
Comp . Ex. 7	12	821	383	56	4.5	807	853	705	3
Comp . Ex. 8	1	820	380	30	2.7	807	845	640	3
Comp . Ex. 9	1	820	380	56	1.5	807	855	721	3
Comp . Ex. 10	1	820	380	56	4.5	807	864	650	3
Comp . Ex. 11	1	820	380	60	4.5	807	861	710	3
Comp . Ex. 12	1	820	380	56	4.5	807	851	721	3
Comp . Ex. 13	1	820	380	46	2.0	807	856	716	3
Ar3(°C) = 910 - 203√C + 44.7Si + 31.5Mo Ms(°C) = 539 - 423C - 30.4Mn - 7.5Si + 30Al - 17.7Ni - 12.1Cr - 7.5Mo Ac3(°C) = 875 - 206C + 26.2Si - 25.0Mn - 12.3Cr + 9.12Mo + 50.2Nb + 148Ti - 131B									

[Table 3]

Cate gory	Stee l No.	2nd Cool End Temp . (T2) (°C)	2nd Avg. Cool Rate (°C/ s)	T1-T2 (°C)	Rehe at/ Over -age Temp . (H) (°C)	Over -age Time (min)	H-T2 (°C)	Skin Pass Forc e (ton)	Tens ion Leve l Elon g. (%)
Inv. Ex. 1	1	98	65	622	175	8.6	77	650	0.15
Inv. Ex. 2	2	95	120	650	175	8.5	80	650	0.15
Inv. Ex. 3	3	105	61	610	185	9.1	80	650	0.15
Inv. Ex. 4	4	103	62	628	176	8.9	73	650	0.15
Inv. Ex. 5	5	105	62	627	175	8.6	70	650	0.15
Comp . Ex. 1	6	97	75	633	173	8.3	76	650	0.70
Comp . Ex. 2	7	102	85	623	181	7.9	79	650	0.70
Comp . Ex. 3	8	95	90	641	191	8.1	96	650	0.85
Comp . Ex. 4	9	105	87	610	187	8.3	82	550	0.90
Comp . Ex. 5	10	97	78	614	185	8.9	88	650	0.15
Comp . Ex. 6	11	97	63	618	189	8.5	92	650	0.15

EP 4 826 080 A1

(continued)

Category	Steel No.	2nd Cool End Temp. (T2) (°C)	2nd Avg. Cool Rate (°C/s)	T1-T2 (°C)	Reheat/Over-age Temp. (H) (°C)	Over-age Time (min)	H-T2 (°C)	Skin Pass Force (ton)	Tension Level Elong. (%)
Comp. Ex. 7	12	97	64	608	191	8.9	94	650	0.15
Comp. Ex. 8	1	98	84	542	178	8.9	80	250	0.15
Comp. Ex. 9	1	300	67	421	167	8.7	-133	250	0.15
Comp. Ex. 10	1	121	65	529	179	8.5	58	250	0.15
Comp. Ex. 11	1	320	67	390	361	8.7	41	250	0.15
Comp. Ex. 12	1	125	61	596	320	8.5	195	250	0.15
Comp. Ex. 13	1	40	560	676	184	8.5	144	250	0.75

[Table 4]

Category	Microstructure (Area %)				a/b	KAM value 0-1.0° Region Fraction (%)		m<n Satisfied
	Surface Layer		Center			Surface Layer (n)	Center (m)	
	F and B or more (b)	M and T or more	F and B or more (a)	M and T or more				
Inv. Ex. 1	3	97	1	99	0.33	39	22	○
Inv. Ex. 2	2	98	1	99	0.50	35	19	○
Inv. Ex. 3	3	97	1	99	0.33	38	23	○
Inv. Ex. 4	2	98	1	99	0.50	39	20	○
Inv. Ex. 5	2	98	1	99	0.50	41	21	○
Comp. Ex. 1	2	98	1	99	0.50	39	19	○
Comp. Ex. 2	2	98	1	99	0.50	37	20	○
Comp. Ex. 3	3	97	3	97	1.00	37	20	○
Comp. Ex. 4	3	97	2	98	0.67	49	21	○
Comp. Ex. 5	13	87	11	89	0.85	56	32	○
Comp. Ex. 6	20	80	15	85	0.75	60	35	○
Comp. Ex. 7	2	98	1	99	0.50	36	20	○
Comp. Ex. 8	15	85	18	82	1.20	56	38	○
Comp. Ex. 9	11	89	17	83	1.55	42	35	○
Comp. Ex. 10	19	81	17	83	0.89	65	23	○
Comp. Ex. 11	17	83	15	85	0.88	60	38	○
Comp. Ex. 12	13	87	8	92	0.62	37	35	○
Comp. Ex. 13	2	98	4	96	2.00	20	21	×
F: Ferrite, B: Bainite, M: Martensite, TM: Tempered Martensite								

[Table 5]

Category	Avgage Carbide Size (nm)	Maximum MnS Inclusion Size (μm)	Surface Roughness		
			Rsk	Pc	Rsk×PC
Inv. Ex. 1	59	10	-0.41	164	-67

EP 4 826 080 A1

(continued)

	Category	Avgage Carbide Size (nm)	Maximum MnS Inclusion Size (μm)	Surface Roughness		
				Rsk	Pc	Rsk $\times$ PC
5	Inv. Ex. 2	65	9	-0.38	179	-68
	Inv. Ex. 3	52	9	-0.31	190	-59
	Inv. Ex. 4	56	11	-0.35	178	-62
10	Inv. Ex. 5	46	9	-0.40	151	-60
	Comp. Ex. 1	84	8	-0.39	136	-53
	Comp. Ex. 2	75	10	-0.42	157	-66
	Comp. Ex. 3	89	9	-0.41	149	-61
15	Comp. Ex. 4	101	18	-0.61	159	-97
	Comp. Ex. 5	87	11	-0.55	169	-93
	Comp. Ex. 6	62	8	-0.45	167	-75
20	Comp. Ex. 7	87	65	-0.41	171	-70
	Comp. Ex. 8	58	11	-0.79	197	-156
	Comp. Ex. 9	56	10	-0.71	201	-143
	Comp. Ex. 10	58	10	-0.71	185	-76
25	Comp. Ex. 11	221	9	-0.70	189	-76
	Comp. Ex. 12	215	8	-0.78	189	-91
	Comp. Ex. 13	53	10	-0.72	215	-155

30

[Table 6]

	Category	Yield Strength (YS) (MPa)	YS / number fraction (m) of a region where the KAM value is 0 to 1.0° in the central portion (MPa/%)	Tensile Strength (TS) (MPa)	Yield Ratio	Elongation (EL) (%)	EL $\times$ number fraction (m) of a region where the KAM value is 0 to 1.0° in the central portion (% ²)
35	Inv. Ex. 1	1294	59	1574	0.82	7	154
	Inv. Ex. 2	1425	75	1756	0.81	7	133
40	Inv. Ex. 3	1274	55	1551	0.82	7	161
	Inv. Ex. 4	1297	65	1589	0.82	6	120
	Inv. Ex. 5	1261	60	1567	0.80	7	147
45	Comp. Ex. 1	2125	112	2205	0.96	3	57
	Comp. Ex. 2	1852	93	1925	0.96	3	60
	Comp. Ex. 3	1478	74	1535	0.96	4	80
	Comp. Ex. 4	1499	71	1567	0.96	3	63
50	Comp. Ex. 5	1105	35	1415	0.78	8	256
	Comp. Ex. 6	1095	31	1395	0.78	8	280
	Comp. Ex. 7	1275	64	1565	0.81	5	100
55	Comp. Ex. 8	1101	29	1465	0.75	7	163
	Comp. Ex. 9	1267	36	1589	0.80	7	151
	Comp. Ex. 10	1150	50	1455	0.76	7	9
	Comp. Ex. 11	1020	27	1395	0.73	9	163

(continued)

Category	Yield Strength (YS) (MPa)	YS / number fraction (m) of a region where the KAM value is 0 to 1.0° in the central portion (MPa/%)	Tensile Strength (TS) (MPa)	Yield Ratio	Elongation (EL) (%)	EL × number fraction (m) of a region where the KAM value is 0 to 1.0° in the central portion (% ²)
Comp. Ex. 12	1380	39	1467	0.94	4	175
Comp. Ex. 13	1477	70	1536	0.96	3	105

[Table 7]

Category	Bendability (R/t)	Rsk×(R/t)	3-Point Bending Angle (°)	Weld Hardness (Hv)	CTS (kN)	Surface Residual Stress (MPa)	Perforation Corrosion Occurrence
Inv. Ex. 1	2.9	1.19	62	520	6.5	-53	Not occurred
Inv. Ex. 2	3.5	1.33	59	602	5.2	-56	Not occurred
Inv. Ex. 3	2.9	0.90	60	531	6.2	-49	Not occurred
Inv. Ex. 4	2.9	1.02	58	565	5.3	-57	Not occurred
Inv. Ex. 5	2.9	1.16	61	517	6.5	-46	Not occurred
Comp. Ex. 1	5.0	1.95	32	836	1.0	2	Not occurred
Comp. Ex. 2	4.6	1.93	36	726	1.9	-1	Not occurred
Comp. Ex. 3	4.6	1.89	40	548	5.7	8	Occurred
Comp. Ex. 4	4.3	2.62	46	658	3.9	25	Not occurred
Comp. Ex. 5	2.5	1.38	61	347	7.5	-45	Not occurred
Comp. Ex. 6	2.5	1.13	62	436	7.0	-56	Not occurred
Comp. Ex. 7	5.0	2.05	37	529	0.6	-61	Not occurred
Comp. Ex. 8	4.3	3.40	39	521	6.7	-51	Not occurred
Comp. Ex. 9	4.3	3.53	39	512	6.6	-57	Not occurred
Comp. Ex. 10	4.3	3.35	38	522	5.9	-61	Not occurred
Comp. Ex. 11	4.3	3.53	47	520	6.7	-61	Not occurred
Comp. Ex. 12	5.0	3.95	38	519	6.5	-51	Not occurred
Comp. Ex. 13	5	4.05	35	518	6.2	6	Not occurred

[0116] As can be seen from Tables 1 to 7, in the case of Invention Examples 1 to 5, which satisfy the alloy composition and manufacturing conditions of the present disclosure, by securing the desired microstructure, the number fraction of the region where the KAM value is 0-1.0°, a/b, the average size of carbides within the laths of tempered martensite, the size of MnS inclusions, the surface roughness (Rsk) of the surface layer, and the surface layer residual stress, it can be seen that not only the mechanical properties but also the shape are excellent, and the spot weldability and corrosion resistance are at an excellent level.

[0117] It can be seen that in Comparative Example 1, which does not satisfy the C content, X value, and tension leveling elongation, the yield strength, tensile strength, yield ratio, elongation, EL×m, bendability, 3-point bending angle, weld strength, CTS, and surface layer residual stress desired by the present disclosure are not secured.

[0118] It can be seen that in Comparative Example 2, which does not satisfy the Si content, X value, and tension leveling elongation, the yield strength, tensile strength, yield ratio, elongation, EL×m, bendability, 3-point bending angle, weld strength, CTS, and surface layer residual stress desired by the present disclosure are not secured.

[0119] It can be seen that in Comparative Example 3, which does not satisfy the Cr content, Y/X value, Z value, and tension leveling elongation, the a/b ratio is not satisfied, and accordingly, the yield ratio, bendability, 3-point bending angle, and surface layer residual stress desired by the present disclosure are not secured, and perforation corrosion

has occurred.

[0120] It can be seen that in Comparative Example 4, which does not satisfy the Si content, X value, Y/X value, and tension leveling elongation, the yield ratio, elongation, $EL \times m$, bendability, $Rsk \times$ bendability, weld strength, CTS, and surface layer residual stress desired by the present disclosure are not secured.

[0121] It can be seen that in Comparative Example 5, which does not satisfy the C content, X value, Y value, Z value, and coiling temperature, the microstructure, a/b, and the number fraction of the region where the KAM value is 0-1.0° are not satisfied, and accordingly, the YS/m, tensile strength, and $EL \times m$ desired by the present disclosure are not secured.

[0122] It can be seen that in Comparative Example 6, which does not satisfy the Cr content, Mo content, B content, X value, and Z value, the microstructure and the number fraction of the region where the KAM value is 0-1.0° are not satisfied, and accordingly, the YS/m, tensile strength, and $EL \times m$ desired by the present disclosure are not secured.

[0123] It can be seen that in Comparative Example 7, which does not satisfy the S content, the maximum size of MnS is not satisfied, and accordingly, the bendability, 3-point bending angle, and CTS desired by the present disclosure are not secured.

[0124] It can be seen that in Comparative Example 8, which does not satisfy the cold reduction ratio, the first cooling end temperature, and the skin pass rolling force, the microstructure, a/b, Rsk, the number fraction of the region where the KAM value is 0-1.0°, Rsk, and $Rsk \times Pc$ are not satisfied, and accordingly, the YS/m, tensile strength, and $Rsk \times$ bendability desired by the present disclosure are not secured.

[0125] It can be seen that in Comparative Example 9, which does not satisfy the surface roughness of the cold rolling roll, H-T2, and the skin pass rolling force, the microstructure, a/b, the number fraction of the region where the KAM value is 0-1.0° in the central portion, and Rsk are not satisfied, and accordingly, the YS/m and $Rsk \times$ bendability desired by the present disclosure are not secured.

[0126] It can be seen that in Comparative Example 10, which does not satisfy the first cooling end temperature and the skin pass rolling force, the microstructure, a/b, the number fraction of the region where the KAM value is 0-1.0° in the surface layer portion, and Rsk are not satisfied, and accordingly, the tensile strength desired by the present disclosure is not secured.

[0127] It can be seen that in Comparative Example 11, which does not satisfy the first average cooling rate, the reheating/over-aging treatment temperature, and the skin pass rolling force, the microstructure, a/b, the number fraction of the region where the KAM value is 0-1.0°, the average carbide size, and Rsk are not satisfied, and accordingly, the yield strength, YS/m, tensile strength, and $Rsk \times$ bendability desired by the present disclosure are not secured.

[0128] It can be seen that in Comparative Example 12, which does not satisfy the reheating/over-aging treatment temperature and the skin pass rolling force, the microstructure, the number fraction of the region where the KAM value is 0-1.0° in the central portion, the average carbide size, and Rsk are not satisfied, and accordingly, the YS/m, tensile strength, $Rsk \times$ bendability, and 3-point bending angle desired by the present disclosure are not secured.

[0129] It can be seen that in Comparative Example 13, which does not satisfy the surface roughness of the cold rolling roll, the second cooling end temperature, the second average cooling rate, T1-T2, the skin pass rolling force, and the tension leveling elongation, a/b, $m < n$, Rsk, and $Rsk \times Pc$ are not satisfied, and accordingly, the yield ratio, bendability, $Rsk \times$ bendability, 3-point bending angle, and surface layer residual stress desired by the present disclosure are not secured.

[0130] FIG. 1 is a TEM photograph of Invention Example 1. FIG. 2 is a TEM photograph of Comparative Example 12. As can be seen from FIGS. 1 and 2, in the case of Invention Example 1, the desired average carbide size is secured, whereas in the case of Comparative Example 13, it can be seen that the average carbide size of the decarburized layer proposed by the present disclosure is not secured.

[0131] FIG. 3 is a photograph of Invention Example 1 after a bare sheet corrosion resistance evaluation. FIG. 4 is a photograph of Comparative Example 3 after a bare sheet corrosion resistance evaluation. As can be seen from FIGS. 3 and 4, in the case of Invention Example 1, perforation corrosion did not occur, whereas in the case of Comparative Example 3, it can be seen that perforation corrosion occurred.

Claims

1. A cold-rolled steel sheet comprising, by weight %: carbon (C): 0.150 to 0.350%, silicon (Si): 0.0050 to 0.70%, manganese (Mn): 0.30 to 2.50%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, phosphorus (P): 0.030% or less (excluding 0%), and sulfur (S): 0.0070% or less (excluding 0%), with the remainder being Fe and other unavoidable impurities,

wherein the steel sheet is divided into: a central portion; and a surface layer portion formed on an outer side of

the central portion in a thickness direction, and

wherein a surface roughness (Rsk) of the surface layer portion is -0.65 to 0.65.

(wherein the surface layer portion refers to a region up to 20 μm from a surface of the steel material in the thickness direction).

2. The cold-rolled steel sheet of claim 1, wherein a product of the surface roughness (Rsk) and Pc of the surface layer portion is -150 or more.

3. The cold-rolled steel sheet of claim 1, wherein an absolute value of a product of the surface roughness (Rsk) and a bendability (R/t) of the surface layer portion is 2.4 or less.

4. A cold-rolled steel sheet comprising, by weight %: carbon (C): 0.150 to 0.350%, silicon (Si): 0.0050 to 0.70%, manganese (Mn): 0.30 to 2.50%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, phosphorus (P): 0.030% or less (excluding 0%), and sulfur (S): 0.0070% or less (excluding 0%), with the remainder being Fe and other unavoidable impurities,

wherein the steel sheet is divided into: a central portion; and a surface layer portion formed on an outer side of the central portion in a thickness direction,

wherein, in an EBSD measurement, when a number fraction of a region where a KAM value is 0 to 5.0° is 100%,

a number fraction (m) of a region where the KAM value is 0 to 1.0° in the central portion is 30% or less (excluding 0%), a number fraction (n) of a region where the KAM value is 0 to 1.0° in the surface layer portion is 55% or less (excluding 0%), and

the number fraction (m) of the region where the KAM value is 0 to 1.0° in the central portion and the number fraction (n) of the region where the KAM value is 0 to 1.0° in the surface layer portion have a relationship of $m < n$.

(wherein the surface layer portion refers to a region up to 20 μm from a surface of the steel material in the thickness direction).

5. The cold-rolled steel sheet of claim 1 or 4, further comprising one or more selected from the group consisting of: boron (B): 0.00050 to 0.0050%, aluminum (Al): 0.010 to 0.10%, niobium (Nb): 0.0010 to 0.10%, titanium (Ti): 0.0050 to 0.080%, and nitrogen (N): 0.010% or less (excluding 0%).

6. The cold-rolled steel sheet of claim 1 or 4, satisfying the following Formulas 1 to 4:

$$[\text{Formula 1}] \quad X = C + 0.03\text{Si} + 0.02\text{Mn}: 0.24 \text{ to } 0.40$$

$$Y = (\text{Cr} + 0.8\text{C} + 0.07(\text{Si} + \text{Mn}) - 0.1\text{Mo} - 50\text{B} - 70\text{P} - 30\text{S}) \times 100 + 100: 30 \text{ to } 120 \quad [\text{Formula 2}]$$

$$[\text{Formula 3}] \quad Y/X = 125 \text{ to } 375$$

$$Z = 48.8 + 49\log C + 35.1\text{Mn} + 25.9\text{Si} + 76.5\text{Cr} + 105.9\text{Mo} + 1325\text{Nb} + 10000\text{B}: 55 \text{ to } 250 \quad [\text{Formula 4}]$$

(wherein the content of each alloying element in Formulas 1 to 4 is in weight %).

7. The cold-rolled steel sheet of claim 1 or 4, wherein a microstructure of the central portion comprises, by area %: a total fraction (a) of one or more of ferrite and bainite of 5% or less (excluding 0%), with the remainder being one or more of martensite and tempered martensite, and

wherein a microstructure of the surface layer portion comprises, by area %: a total fraction (b) of one or more of ferrite and bainite of 10% or less (excluding 0%), with the remainder being one or more of martensite and tempered martensite.

8. The cold-rolled steel sheet of claim 7, wherein a and b have a relationship of $0.1 < a/b < 0.8$.

9. The cold-rolled steel sheet of claim 7, wherein an average size of carbides within laths of the tempered martensite is 200 nm or less (excluding 0 nm).

10. The cold-rolled steel sheet of claim 1 or 4, wherein a maximum size of MnS inclusions is 50 μm or less (excluding 0 μm).

11. The cold-rolled steel sheet of claim 1 or 4, wherein a residual stress of the surface layer portion is -30 MPa or less.

12. The cold-rolled steel sheet of claim 1 or 4, wherein the cold-rolled steel sheet has a yield strength of 1050 to 1700 MPa, a tensile strength of 1470 to 1900 MPa, a yield ratio of 0.65 to 0.95, an elongation of 4 to 10%, a bendability (R/t) of 4 or less, and a maximum 3-point bending angle of 40° or more.

13. The cold-rolled steel sheet of claim 1 or 4, wherein a product of a number fraction (m) of a region where a KAM value is 0 to 1.0° in the central portion and an elongation is 80 to 210%, and a ratio (YS/m) of a yield strength (YS) to the number fraction (m) of the region where the KAM value is 0 to 1.0° in the central portion is 45 MPa/% or more.

14. The cold-rolled steel sheet of claim 1 or 4, wherein, after resistance spot welding, a hardness of a weld is 650 Hv or less, and a cross-tension strength (CTS) of the weld is 4.5 kN or more.

15. The cold-rolled steel sheet of claim 1 or 4, wherein the cold-rolled steel sheet has zero holes with a diameter of 3 mm or more when subjected to a bare sheet corrosion resistance test for 30 cycles.

16. A method for manufacturing a cold-rolled steel sheet, the method comprising: heating a slab comprising, by weight %: carbon (C): 0.150 to 0.350%, silicon (Si): 0.0050 to 0.70%, manganese (Mn): 0.30 to 2.50%, chromium (Cr): 0.0050 to 0.60%, molybdenum (Mo): 0.0030 to 0.50%, phosphorus (P): 0.030% or less (excluding 0%), and sulfur (S): 0.0070% or less (excluding 0%), with the remainder being Fe and other unavoidable impurities;

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

coiling the hot-rolled steel sheet;

cold rolling the coiled hot-rolled steel sheet at a cold reduction ratio of 35 to 70% using a roll with a surface roughness (Ra) of 2.5 μm or more to obtain a cold-rolled steel sheet;

continuously annealing the cold-rolled steel sheet;

first cooling the continuously annealed cold-rolled steel sheet to a first cooling end temperature (T1) of 660°C to Ac3;

second cooling the first-cooled cold-rolled steel sheet to a second cooling end temperature (T2) of 50 to 300°C;

reheating the second-cooled cold-rolled steel sheet and then over-aging it at an over-aging treatment temperature (H) of 100 to 250°C;

skin pass rolling the over-aged cold-rolled steel sheet with a rolling force of 500 to 1000 tons; and

tension leveling the skin-pass-rolled cold-rolled steel sheet at an elongation of 0.05 to 0.65%.

17. The method of claim 16, wherein the slab further comprises one or more selected from the group consisting of: boron (B): 0.00050 to 0.0050%, aluminum (Al): 0.010 to 0.10%, niobium (Nb): 0.0010 to 0.10%, titanium (Ti): 0.0050 to 0.080%, and nitrogen (N): 0.010% or less (excluding 0%).

18. The method of claim 16, wherein the slab satisfies the following Formulas 1 to 4:

$$[\text{Formula 1}] \quad X = C + 0.03\text{Si} + 0.02\text{Mn}: 0.24 \text{ to } 0.40$$

$$Y = (\text{Cr} + 0.8\text{C} + 0.07(\text{Si} + \text{Mn}) - 0.1\text{Mo} - 50\text{B} - 70\text{P} - 30\text{S}) \times 100 + 100: 30 \text{ to } 120 \quad [\text{Formula 2}]$$

$$[\text{Formula 3}] \quad Y/X = 125 \text{ to } 375$$

$$Z = 48.8 + 49\log C + 35.1\text{Mn} + 25.9\text{Si} + 76.5\text{Cr} + 105.9\text{Mo} + 1325\text{Nb} + 10000\text{B}: 55 \text{ to } 250 \quad [\text{Formula 4}]$$

(wherein the content of each alloying element in Formulas 1 to 4 is in weight %).

19. The method of claim 16, wherein the slab heating is performed at 1100 to 1300°C.

20. The method of claim 16, wherein the finish hot rolling is performed at Ar3 to Ar3+120°C.

21. The method of claim 16, wherein the coiling is performed at Ms to 700°C.

5 **22.** The method of claim 16, wherein the continuous annealing is performed at Ac3 to Ac3+100°C for 30 to 230 seconds.

23. The method of claim 16, wherein the first cooling is performed at an average cooling rate of 1 to 6°C/s.

10 **24.** The method of claim 16, wherein the second cooling is performed at an average cooling rate of 30 to 300°C/s.

25. The method of claim 16, wherein, during the first and second cooling, a difference between the first cooling end temperature (T1) and the second cooling end temperature (T2) is controlled to be 650°C or less.

15 **26.** The method of claim 16, wherein the over-aging treatment is performed for 5 to 12 minutes.

27. The method of claim 16, wherein, during the second cooling and over-aging treatment, a difference between the over-aging treatment temperature (H) and the second cooling end temperature (T2) is controlled to be 30°C or more.

20

25

30

35

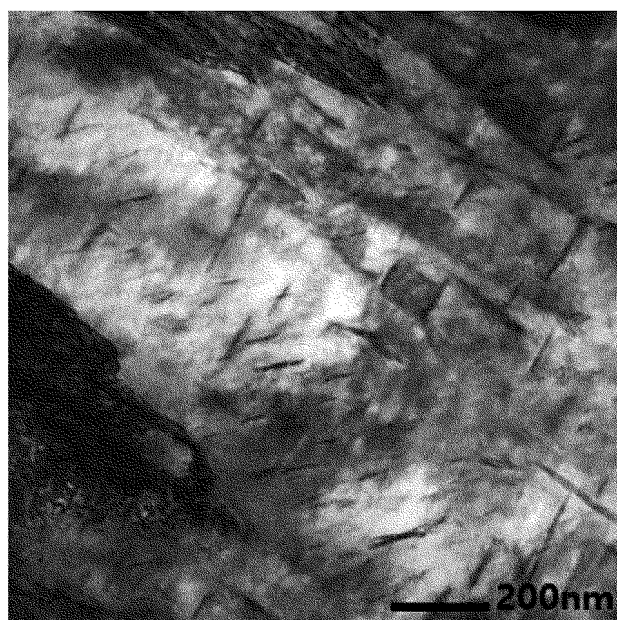
40

45

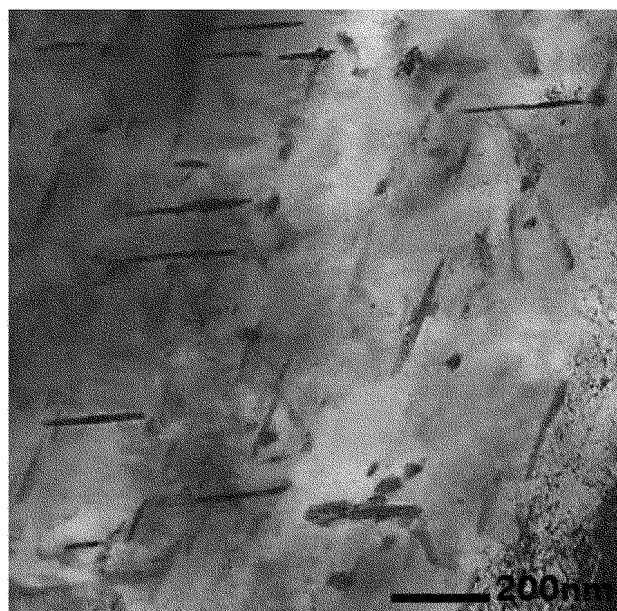
50

55

[Fig. 1]



[Fig. 2]



[Fig. 3]



[Fig. 4]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2024/020434

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/38(2006.01)i; C22C 38/22(2006.01)i; C22C 38/32(2006.01)i; C22C 38/06(2006.01)i; C22C 38/00(2006.01)i;
C22C 38/28(2006.01)i; C22C 38/26(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); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/04(2006.01); C22C 38/06(2006.01);
C22C 38/14(2006.01); C22C 38/34(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: 표면조도(Rsk, skewness), 커널 방위차(KAM, kernel average misorientation), 과시효(over aging), 냉각속도(cooling velocity)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-0611541 B1 (JFE STEEL CORPORATION) 10 August 2006 (2006-08-10) See claims 1-3 and 5.	1-27
A	JP 2010-255090 A (KOBE STEEL LTD.) 11 November 2010 (2010-11-11) See claims 1-3 and 5.	1-27
A	KR 10-2022-0086193 A (POSCO) 23 June 2022 (2022-06-23) See claims 1 and 7-12.	1-27
A	KR 10-2014-0129316 A (KABUSHIKI KAISHA KOBE SEIKO SHO (KOBE STEEL, LTD.)) 06 November 2014 (2014-11-06) See claims 1, 3 and 8.	1-27
A	JP 2014-196557 A (KOBE STEEL LTD.) 16 October 2014 (2014-10-16) See claims 1, 3 and 5.	1-27

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search 18 March 2025	Date of mailing of the international search report 19 March 2025
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon Building 4, 189 Cheongsaro, Seo-gu, Daejeon 35208 Facsimile No. +82-42-481-8578	Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/KR2024/020434

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-0611541 B1	10 August 2006	CA 2380377 A1	06 December 2001
		CA 2380377 C	09 January 2007
		CN 1152970 C	09 June 2004
		CN 1386141 A	18 December 2002
		DE 60110586 T2	01 December 2005
		EP 1291447 A1	12 March 2003
		EP 1291447 B1	04 May 2005
		JP 2002-053931 A	19 February 2002
		JP 4839527 B2	21 December 2011
		KR 10-2002-0036838 A	16 May 2002
		TW 500809 B	01 September 2002
		US 2003-0047257 A1	13 March 2003
		US 6695932 B2	24 February 2004
		WO 01-92593 A1	06 December 2001
JP 2010-255090 A	11 November 2010	CN 102341518 A	01 February 2012
		CN 102341518 B	10 April 2013
		EP 2415891 A1	08 February 2012
		JP 2010-255091 A	11 November 2010
		JP 4977184 B2	18 July 2012
		JP 4977185 B2	18 July 2012
		US 2012-0012231 A1	19 January 2012
		US 8840738 B2	23 September 2014
		WO 2010-114131 A1	07 October 2010
KR 10-2022-0086193 A	23 June 2022	CN 116547401 A	04 August 2023
		EP 4265781 A1	25 October 2023
		JP 2024-500722 A	10 January 2024
		KR 10-2461164 B1	02 November 2022
		US 2024-0052468 A1	15 February 2024
		WO 2022-131619 A1	23 June 2022
KR 10-2014-0129316 A	06 November 2014	CN 104204259 A	10 December 2014
		CN 104204259 B	08 March 2017
		JP 2013-227654 A	07 November 2013
		JP 5764549 B2	19 August 2015
		KR 10-2017-0002674 A	06 January 2017
		KR 10-2019-0064681 A	10 June 2019
		MX 2014011619 A	17 October 2014
		US 2015-0086808 A1	26 March 2015
		US 2020-0095651 A1	26 March 2020
		WO 2013-146148 A1	03 October 2013
JP 2014-196557 A	16 October 2014	JP 6291289 B2	14 March 2018

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2010248565 A [0007]
- JP 2020019992 A [0007]