



(11)

EP 4 826 045 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: **24903121.2**

(22) Date of filing: **30.12.2024**

(51) International Patent Classification (IPC):
C22C 38/04 (2006.01) **C22C 38/16** (2006.01)
C22C 38/06 (2006.01) **C22C 38/14** (2006.01)
C22C 38/12 (2006.01) **C21D 8/02** (2026.01)
C21D 9/46 (2006.01) **C23C 2/06** (2006.01)

(52) Cooperative Patent Classification (CPC):
C21D 8/02; C21D 9/46; C22C 38/04; C22C 38/06;
C22C 38/12; C22C 38/14; C22C 38/16; C23C 2/06

(86) International application number:
PCT/IB2024/063304

(87) International publication number:
WO 2025/126189 (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 20230183834**

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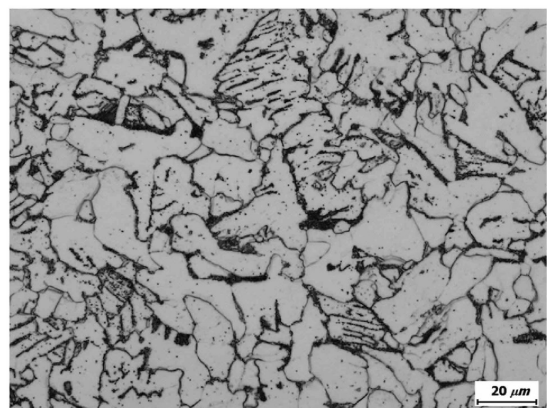
Remarks:

The filing date of the international application is within two months from the date of expiration of the priority period (R. 26bis.3 PCT)

(54) **HIGH-STRENGTH THIN COLD-ROLLED STEEL SHEET, GALVANIZED STEEL SHEET, AND MANUFACTURING METHOD THEREOF**

(57) A cold-rolled steel sheet according to an embodiment of the present invention comprises, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities, wherein an area fraction of ferrite in the steel sheet is 80% or more.

FIG. 1



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Description**[Technical Field]**

5 **[0001]** An embodiment of the present invention relates to a high strength and thin gauge cold-rolled steel sheet, a galvanized steel sheet, and manufacturing methods thereof. More specifically, an embodiment of the present invention relates to a high strength and thin gauge cold-rolled steel sheet, a galvanized steel sheet, and manufacturing methods thereof that may be utilized for refrigerators, washing machines, outdoor units of air conditioners, dishwashers, kitchen appliances, and the like.

[Background Art]

10 **[0002]** Recently, the reduction of carbon emissions has emerged as a social issue, and as part of continuous efforts to reduce costs, customers using steel materials are tending to require thin-gauging of the steel products used. However, since steel is mainly utilized for rigidity support purposes, especially in the home appliance field, simple thin-gauging may cause a decrease in rigidity. In order to enable thin-gauging without reducing the rigidity of the product, high strength of the material is required, specifically a material in which the yield strength is increased compared to conventionally used materials. However, since an increase in yield strength causes a decrease in formability, such as a decrease in elongation, a material having an appropriate elongation and yield strength must be developed. CQ (Commercial Quality) grade and DQ (Drawing Quality) grade materials mainly used as conventional parts for home appliances have a strength level of 150 to 250 MPa based on yield strength and an elongation level of 35 to 55%. As a way to increase strength while minimizing the decrease in elongation compared to such conventional materials, the use of steel grades having a yield strength of 300 or 340 MPa grade as a lower limit is gradually increasing recently.

20 **[0003]** Steel grades with high yield strength present several issues in terms of utilization, but there are also many factors to consider in terms of manufacturing. In particular, when the final cold-rolled material is a thin gauge material, it is necessary to additionally review the thickness of the hot-rolled material, which serves as the substrate for the cold-rolled material. When the hot-rolled material thickness is increased in consideration of hot rollability, a problem arises in that the cold reduction ratio increases, leading to a higher load during cold reduction; however, to lower the cold reduction ratio, the problem of inevitably having to perform hot rolling to a thin gauge arises.

30 **[0004]** In addition, in the case of utilizing precipitate-forming elements such as Ti and Nb, which were mainly used for achieving high strength in the past, precipitates such as TiN, TiS, TiC, and Nb(C,N) are formed in a complex manner depending on manufacturing conditions in a hot rolling process, and additional precipitates are formed in an annealing process after cold rolling. Accordingly, if the temperature during the manufacturing process is not strictly controlled, deviations in material properties occur due to temperature deviations in the longitudinal and transverse directions of the final cold-rolled steel sheet, leading to a problem where hot rolling manufacturing conditions or annealing conditions after cold rolling must be controlled, or additional equipment must be utilized to minimize temperature changes.

[Disclosure]**[Technical Problem]**

45 **[0005]** An embodiment of the present invention provides a high strength and thin gauge cold-rolled steel sheet, a galvanized steel sheet, and manufacturing methods thereof. More specifically, an embodiment of the present invention provides a high strength thin gauge cold-rolled steel sheet, a galvanized steel sheet, and manufacturing methods thereof that may be utilized for refrigerators, washing machines, outdoor units of air conditioners, dishwashers, kitchen appliances, and the like.

[Technical Solution]

50 **[0006]** A cold-rolled steel sheet according to an embodiment of the present invention comprises, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities, wherein an area fraction of ferrite in the steel sheet is 80% or more.

55 **[0007]** A cold-rolled steel sheet according to an embodiment of the present invention may satisfy the following Equation 1.

[Equation 1]

$$571 \times [C] + 63 \times [Mn] \geq 140$$

[0008] (In Equation 1, [C] and [Mn] are the contents (wt%) of C and Mn, respectively.)

A cold-rolled steel sheet according to an embodiment of the present invention may further comprise at least one of Ti: 0.01 wt% or less and Nb: 0.01 wt% or less.

[0009] In a cold-rolled steel sheet according to an embodiment of the present invention, a sum of area fractions of bainite, martensite, and pearlite may be 10% or less.

[0010] A cold-rolled steel sheet according to an embodiment of the present invention may have a thickness of 1.0 mm or less.

[0011] In a cold-rolled steel sheet according to an embodiment of the present invention, cracks may not be formed in a bending part when the steel sheet is subjected to a bending test under a load of 10 tons using a V-bending die having a radius of curvature of $r=0$.

[0012] A cold-rolled steel sheet according to an embodiment of the present invention may have a yield strength of 340 MPa or more, a tensile strength of 450 MPa or more, and an elongation of 20% or more.

[0013] A method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention comprises the steps of: manufacturing a hot-rolled steel sheet by hot rolling a slab comprising, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities; manufacturing a cold-rolled steel sheet by cold rolling the hot-rolled steel sheet; and annealing the cold-rolled steel sheet.

[0014] In the step of manufacturing a hot-rolled steel sheet, finish rolling may be performed at a temperature of 850 °C or higher, and coiling may be performed at a temperature of 610 °C or higher.

[0015] In the step of manufacturing the cold-rolled steel sheet, the reduction ratio may be 70% or more.

[0016] In the annealing step, soaking may be performed at 750 to 830 °C, and cooling may be performed from the soaking temperature to 550 °C at a cooling rate of 35 °C/sec or less.

[0017] Before the step of manufacturing the hot-rolled steel sheet, a step of heating the slab at 1100 °C or higher for 150 minutes or more may be further included.

[0018] The slab may have a maximum stress value of 180 MPa or less when a compression test is performed up to a strain of 1.2 at a temperature of 900 °C after heating at a heating rate of 20 °C/sec, maintaining the slab at 1200 °C for 3 minutes, and then cooling at a cooling rate of 10 °C/sec.

[0019] In the step of manufacturing a hot-rolled steel sheet, rough rolling may be finished at a temperature of 950 °C or higher.

[0020] After the step of manufacturing the hot-rolled steel sheet, the average grain diameter of the hot-rolled steel sheet may be 20 μm or more.

[0021] After the step of manufacturing the hot-rolled steel sheet, the hot-rolled steel sheet may comprise 20 area % or less of carbide.

[0022] A galvanized steel sheet according to an embodiment of the present invention includes a galvanized layer on a surface of the aforementioned cold-rolled steel sheet.

[Advantageous Effects]

[0023] A high strength and thin cold-rolled steel sheet according to an embodiment of the present invention may be utilized in various fields, and in particular, may be effectively utilized for refrigerator door or cavity applications in home appliance companies.

[0024] When a high strength and thin gauge cold-rolled steel sheet according to an embodiment of the present invention is utilized for home appliances, there is an effect of reducing the weight of steel used per home appliance unit due to gauge reduction, which is environmentally friendly because carbon emissions generated in producing individual products may be reduced.

[0025] In addition, a high strength and thin gauge cold-rolled steel sheet according to an embodiment of the present invention is economical because elements such as Nb and Ti may be excluded, and is environmentally friendly because the emission of chemical impurities in the process of producing the elements may be reduced.

[Brief Description of the Drawings]

[0026]

Fig. 1 is an optical micrograph showing the microstructure of the hot-rolled steel sheet manufactured in Inventive Example 1.

Fig. 2 is an optical micrograph showing the microstructure of the hot-rolled steel sheet manufactured in Comparative Example 8.

Fig. 3 is a photograph of the cold-rolled steel sheet manufactured in Inventive Example 1 after a V-bending test.

Fig. 4 is a photograph of the cold-rolled steel sheet manufactured in Comparative Example 4 after a V-bending test.

[Mode for Invention]

[0027] Terms such as first, second, and third are used to describe various parts, components, regions, layers, and/or sections, but are not limited thereto. These terms are only used to distinguish one part, component, region, layer, or section from another part, component, region, layer, or section. Accordingly, a first part, component, region, layer, or section described below may be referred to as a second part, component, region, layer, or section without departing from the scope of the present invention.

[0028] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. The term "comprising" used in the specification specifies the presence of stated characteristics, regions, integers, steps, operations, elements, and/or components, but does not preclude the presence or addition of one or more other characteristics, regions, integers, steps, operations, elements, components, and/or groups thereof.

[0029] When a part is referred to as being "above" or "on" another part, it may be directly above or on the other part, or an intervening part may be present therebetween. In contrast, when a part is referred to as being "directly above" another part, no other part is interposed therebetween.

[0030] Unless otherwise defined, all terms including technical and scientific terms used herein have the same meaning as commonly understood by a person of ordinary skill in the art to which the present invention belongs. Terms defined in commonly used dictionaries are further interpreted as having a meaning consistent with the related technical literature and the present disclosure, and are not to be interpreted in an idealized or overly formal sense unless defined.

[0031] In addition, unless otherwise specified, % refers to wt%, and 1 ppm is 0.0001 wt%.

[0032] In an embodiment of the present invention, the expression 'further including an additional element' means that the additional element is included by replacing balance iron (Fe) in an amount corresponding to the addition amount of the additional element.

[0033] Hereinafter, embodiments of the present invention will be described in detail so that a person of ordinary skill in the art to which the present invention pertains may easily implement them. However, the present invention may be implemented in various different forms and is not limited to the embodiments described herein.

[0034] A cold-rolled steel sheet according to an embodiment of the present invention comprises, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities.

[0035] The reasons for limiting the alloying elements are described below.

Carbon (C): 0.15 to 0.22 wt%

[0036] Carbon (C) is an element that is dissolved in steel as a solid solution to advantageously improve strength. If the content of C is too low, it is difficult to obtain the desired strength characteristics. If the content of C is too high, a large amount of carbides and hard phases are formed, and degradation of weldability may occur during the production process. More specifically, C may be included in an amount of 0.16 to 0.21 wt%.

Manganese (Mn): 0.75 to 1.20 wt%

[0037] Manganese (Mn) serves to improve the yield strength of the steel by being dissolved in the steel as a solid solution. If Mn is not sufficiently included, it is difficult to ensure the desired strength. If Mn is included in an excessive amount, Mn bands are excessively formed in the microstructure, which may cause cracks when bending is performed in the rolling direction. More specifically, Mn may be included in an amount of 0.77 to 1.15 wt%.

[0038] A cold-rolled steel sheet according to an embodiment of the present invention may satisfy the following Equation 1.

[Equation 1]

$$571 \times [C] + 63 \times [Mn] \geq 140.0$$

[0039] When C and Mn values are adjusted according to the value of Equation 1, the A1 temperature, which is the completion temperature at which ferrite is formed, is lowered, carbide formation in the hot rolling stage is suppressed, and the hot rolling load during hot rolling may be controlled. More specifically, the value of the left hand side of Equation 1 may be 145.0 to 185.0.

Phosphorus (P): 0.005 to 0.020 wt%

[0040] Phosphorus is a representative solid solution strengthening element that may improve strength through solid solution strengthening in steel. If P is not sufficiently included, it is difficult to appropriately perform the aforementioned role. If P is included excessively, cold shortness may be caused. More specifically, P may be included in an amount of 0.010 to 0.015 wt%.

Copper (Cu): 0.005 to 0.070 wt%

[0041] Copper has a low melting point, and when concentrated on the surface, it penetrates into grain boundaries during a reheating process, causing defects in a hot-rolled slab, and these defects may develop into edge scabs during hot rolling. More specifically, copper (Cu) may be included in an amount of 0.010 to 0.050 wt%.

Aluminum (Al): 0.015 to 0.050 wt%

[0042] Aluminum is a representative deoxidizing element added to control oxygen in molten steel in a steelmaking process. When the aluminum content is high, coarse aluminum oxides may remain in the form of inclusions, and such coarse oxides may form cracks when located at a point of high strain. More specifically, aluminum may be included in an amount of 0.020 to 0.035 wt%.

[0043] In an embodiment of the present invention, material deviation along the longitudinal direction and the width direction may be reduced by excluding the addition of expensive Nb and Ti. Specifically, a cold-rolled steel sheet according to an embodiment of the present invention may further comprise at least one of Ti: 0.01 wt% or less and Nb: 0.01 wt% or less. More specifically, it may further comprise at least one of Ti: 0.0001 to 0.01 wt% and Nb: 0.0001 to 0.01 wt%.

[0044] A cold-rolled steel sheet according to an embodiment of the present invention comprises iron (Fe) as the balance. In addition, unavoidable impurities may be included. The term 'unavoidable impurities' refers to impurities inevitably mixed in the process of steelmaking and manufacturing of the cold-rolled steel sheet. Since unavoidable impurities are widely known, a specific description thereof will be omitted. In an embodiment of the present invention, addition of elements other than the aforementioned alloying elements is not excluded, and they may be variously included within a range that does not depart from the technical spirit of the present invention. When additional elements are further included, they are included by replacing a portion of the iron (Fe) as the balance.

[0045] A cold-rolled steel sheet according to an embodiment of the present invention has an area fraction of ferrite in the steel sheet of 80% or more. In an embodiment of the present invention, formability may be further secured by securing ferrite as much as possible. Ferrite may be detected by image analysis using an optical microscope, and the area fraction may be obtained by measuring a cross-section of a rolling specimen including the rolling direction with an optical microscope and an image analysis device. More specifically, the area fraction of ferrite may be 80 to 99 area %.

[0046] The remainder, other than the aforementioned ferrite, may be bainite, martensite, and pearlite. These are hard phases, and when a large amount of these are included, cracks may occur during molding. Accordingly, the sum of the area fractions of bainite, martensite, and pearlite may be controlled to 10% or less. More specifically, it may be 1 to 5 area %.

[0047] A cold-rolled steel sheet according to an embodiment of the present invention has excellent strength, and even when formed into a thin gauge, the strength is excellent. Accordingly, the thickness of the steel sheet may be 1.0 mm or less. More specifically, the thickness may be 0.5 mm or less. More specifically, the thickness may be 0.1 to 0.4 mm.

[0048] In a cold-rolled steel sheet according to an embodiment of the present invention, cracks may not be formed in a bent part when the steel sheet is subjected to a bending test with a load of 10 tons using a V-bending die having a radius of curvature of $r=0$. Cracks may be identified with the naked eye, but in the present invention, a magnifying glass was utilized.

[0049] A cold-rolled steel sheet according to an embodiment of the present invention has excellent mechanical properties. Specifically, the yield strength may be 340 MPa or more, the tensile strength may be 450 MPa or more, and the elongation may be 20% or more. More specifically, the yield strength may be 340 to 430 MPa, the tensile strength may be 450 to 550 MPa, and the elongation may be 20 to 35%. More specifically, the yield strength may be 345 to 420 MPa, the tensile strength may be 480 to 545 MPa, and the elongation may be 21 to 33%. These properties may be measured by performing a uniaxial tensile test after processing the cold-rolled steel sheet into a JIS13B standard specimen.

[0050] A cold-rolled steel sheet according to an embodiment of the present invention may be used as a cold-rolled steel sheet itself, but may also be used through galvanizing. That is, in a galvanized steel sheet according to an embodiment of the present invention, a galvanized layer is present on a surface of the aforementioned cold-rolled steel sheet. Since galvanizing is widely known, a specific description thereof will be omitted.

[0051] A method for manufacturing a cold-rolled steel sheet according to an embodiment of the present invention comprises the steps of: manufacturing a hot-rolled steel sheet by hot rolling a slab comprising, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities; manufacturing a cold-rolled steel sheet by cold rolling the hot-rolled steel sheet; and annealing the cold-rolled steel sheet.

[0052] Since the alloy composition of the slab is the same as that of the aforementioned cold-rolled steel sheet, a redundant description thereof will be omitted. Since the alloying elements do not vary during the manufacturing process of the cold-rolled steel sheet, the alloy compositions of the slab and the cold-rolled steel sheet are substantially the same.

[0053] Before the step of manufacturing the hot-rolled steel sheet, a step of heating the slab at 1100 °C or higher for 150 minutes or more may be further included. By heating the slab, the subsequent hot rolling process may be smoothly performed, and the slab may be subjected to homogenization treatment. More specifically, the slab may be heated at a temperature of 1150 to 1300 °C for 180 to 240 minutes.

[0054] The slab may have a maximum stress value of 180 MPa or less when a compression test is performed up to a strain of 1.2 at a temperature of 900 °C after heating at a heating rate of 20 °C/sec, maintaining at 1200 °C for 3 minutes, and then cooling at a cooling rate of 10 °C/sec. For convenience, the aforementioned stress value is referred to as high temperature compressive stress. High temperature compressive stress may be measured using a Gleeble 3500 device, and may be measured by taking a cylindrical compression test specimen having a diameter of 10 mm and a height of 15 mm from the slab and then performing a compression test using the same.

[0055] By performing the aforementioned compression test, a stress-strain curve is obtained, and the maximum stress value of the stress strain curve is found. If the high temperature compressive stress is too large, the rolling load increases, which may make it difficult to control the thickness during rolling. More specifically, the high temperature compressive stress may be 120 to 175 MPa. As such, the cold-rolled steel sheet according to an embodiment of the present invention has low deformation resistance during hot rolling, which provides excellent ease of manufacturing, and at the same time, high strength may be secured through an annealing heat treatment process after cold rolling while having such low deformation resistance.

[0056] Returning to the description of the manufacturing method of a cold-rolled steel sheet, first, a slab is hot-rolled to manufacture a hot-rolled steel sheet. Hot rolling may be broadly divided into rough rolling to produce a bar, finish rolling to produce a final shape, and a coiling step of coiling the rolled steel sheet.

[0057] In an embodiment of the present invention, rough rolling may be finished at a temperature of 950 °C or higher. By appropriately adjusting the rough rolling finishing temperature, the finishing rolling temperature may be adjusted later, and it contributes to softening in the hot rolling stage. More specifically, the rough rolling finishing temperature may be 950 to 1050 °C.

[0058] In an embodiment of the present invention, finish rolling may be completed at a temperature of 850 °C or higher. In an embodiment of the present invention, the strength of the hot-rolled steel sheet may be optimized by controlling the microstructure and the fraction of carbides of the hot-rolled steel sheet by adjusting the finish rolling delivery temperature (FDT). More specifically, the finishing rolling temperature may be 860 to 1000 °C.

[0059] In an embodiment of the present invention, coiling may be performed at a temperature of 610 °C or higher. If the coiling temperature (CT) is too low, it may be difficult to control the thickness of the hot-rolled steel sheet due to an increase in rolling load during manufacturing of the hot-rolled steel sheet, and cold rolling may become difficult due to an increase in initial strength. More specifically, the coiling temperature may range from 615 to 700 °C.

[0060] The thickness of the coiled hot-rolled steel sheet may be 2.0 to 5.0 mm. The manufactured hot-rolled steel sheet may not have edge cracks.

[0061] As described above, the microstructure and carbides of the hot-rolled steel sheet are controlled by adjusting the finishing delivery temperature (FDT) and the coiling temperature (CT).

[0062] After the step of manufacturing the hot-rolled steel sheet, the average grain diameter of the hot-rolled steel sheet may be 20 μm or more. When the grain diameter is large, it is advantageous in terms of preventing an increase

in load during hot rolling for a thin gauge. More specifically, the average grain diameter of the hot-rolled steel sheet may be 20 to 40 μm . The grain diameter may be obtained by dividing the measurement area by the number of grains through an optical microscope, based on a cross-section including the rolling direction. The grain diameter refers to the diameter of a virtual circle having the same area as the crystal grain.

[0063] After the step of manufacturing the hot-rolled steel sheet, the hot-rolled steel sheet may comprise 20 area % or less of carbide. If a large amount of carbide is generated, a hot rolling load increases, which adversely affects formability. More specifically, the hot-rolled steel sheet may comprise 10 to 20 area % of carbide. The carbide content is a numerical representation of the area occupied by carbide relative to the total area, as observed on a cross-section including the rolling direction with an optical microscope at 500x magnification.

[0064] Thereafter, a step of pickling the hot-rolled steel sheet may be further included.

[0065] Next, a cold-rolled steel sheet is manufactured by cold rolling the hot-rolled steel sheet.

[0066] In the step of manufacturing the cold-rolled steel sheet, the reduction ratio is 70% or more. Increasing the cold reduction ratio may refine the microstructure during cold rolling of the hot-rolled sheet and refine the recrystallized grain diameter during recrystallization in the subsequent annealing process. More specifically, the reduction ratio may be 70 to 90%. The reduction ratio may be obtained as (steel sheet thickness before rolling - steel sheet thickness after rolling) / steel sheet thickness before rolling $\times 100$ (%). After cold rolling, the thickness of the cold-rolled steel sheet may be 1.0 mm or less. More specifically, it may be 0.5 mm or less. More specifically, it may be 0.1 to 0.4 mm.

[0067] Next, the cold-rolled steel sheet is annealed. At this time, the soaking temperature during annealing may be 750 to 830 $^{\circ}\text{C}$. If the soaking temperature is too low, incomplete recrystallization occurs or the fraction of the hard phase in the microstructure increases, making it difficult to ensure sufficient formability. If the soaking temperature is too high, it may be difficult to obtain desired strength characteristics. More specifically, the soaking temperature may be 755 to 825 $^{\circ}\text{C}$. The soaking time may be 40 to 100 seconds.

[0068] Cooling may be performed from the soaking temperature to 550 $^{\circ}\text{C}$ at a cooling rate of 35 $^{\circ}\text{C}/\text{sec}$ or less. If the cooling rate is too fast, hard phases such as bainite or pearlite may be formed in the remaining austenite region. When the hard phases are formed, the material strength increases, but the formability decreases, and in particular, there is a possibility that cracks may occur during V-bending. More specifically, cooling may be performed at a cooling rate of 10 to 25 $^{\circ}\text{C}/\text{sec}$.

[0069] Thereafter, a step of galvanizing the cold-rolled steel sheet may be further included. In the step of galvanizing, various galvanizing methods such as hot-dip galvanizing or electro-galvanizing may be utilized. More specifically, hot-dip galvanizing may be performed in a plating bath at a temperature range of 400 to 500 $^{\circ}\text{C}$, specifically, 420 to 480 $^{\circ}\text{C}$. When the temperature of the hot-dip galvanizing is lower than the lower limit of the temperature range, zinc may not be sufficiently melted and may not be uniformly plated. When the temperature is higher than the upper limit of the temperature range, the plating bath volatilizes, the plating bath combines with the steel sheet during cooling to such an extent that the formation of a sound microstructure is hindered, and there is a problem that the steel sheet melts during the plating process.

[0070] In addition, in electro-galvanizing, an anti-fingerprint resin coating may be performed after plating. The coating may be performed in a temperature range of 100 to 200 $^{\circ}\text{C}$. For example, if the temperature is lower than the lower limit of the temperature range, there is a concern that the coated resin may be dried non-uniformly. If the temperature is higher than the upper limit of the temperature range, there is a concern that an aging phenomenon may occur during the drying process, resulting in an increase in the yield point due to yield point elongation.

[0071] Hereinafter, specific examples of the present invention will be described. However, the following examples are merely specific examples of the present invention, and the present invention is not limited to the following examples.

Example 1

[0072] Steel slabs having the compositions shown in Table 1 below, with the balance being Fe and unavoidable impurities, were manufactured, and the component values are actual measured values.

[0073] A hot-rolled steel sheet was manufactured by heating a slab at 1200 $^{\circ}\text{C}$ for 200 minutes and then hot rolling the slab to a thickness of 2.3 mm. The rough rolling finishing temperature was 1000 $^{\circ}\text{C}$, the finishing delivery temperature (FDT) was 900 $^{\circ}\text{C}$, and coiling was performed at 650 $^{\circ}\text{C}$. A cold-rolled steel sheet was manufactured by applying a reduction ratio of 85% to the hot-rolled steel sheet, and the cold-rolled steel sheet was annealed at 780 $^{\circ}\text{C}$ for 50 seconds and cooled to 550 $^{\circ}\text{C}$ at a cooling rate of 20 $^{\circ}\text{C}/\text{sec}$.

[0074] The characteristics of the slab, hot-rolled steel sheet, and cold-rolled steel sheet were measured by the following methods and summarized in Tables 2 and 3 below.

[0075] Hot-rolled steel sheet grain diameter: Based on a cross-section including the rolling direction, the average area was obtained by dividing the measurement area by the number of crystal grains observed through an optical microscope, and the grain diameter was determined therefrom.

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[0076] Hot-rolled steel sheet carbide: For a cross-section including the rolling direction, the area occupied by carbide in the total area was quantified after observation with an optical microscope at 500x magnification.

[0077] Microstructural area fraction: The area fraction of ferrite and the area fractions of the remaining hard phases (bainite, martensite, and pearlite) were determined by analyzing optical micrographs.

[0078] V-bending test: The steel sheet was subjected to a bending test under a load of 10 tons using a V-bending die having a radius of curvature of $r=0$ to visually check whether cracks occurred in the bent portion.

[0079] Yield strength, tensile strength, and elongation: Measurements were performed by sampling a JIS13B standard specimen and performing a uniaxial tensile test.

[0080] Regarding hot-rolling cracks, cases where a crack of 2.5 mm or more exists were determined to be 'Present' using a magnifying glass for the steel sheet.

[Table 1]

(wt%)	C	Mn	P	Al	Cu	Left side of Formula 1
Inventive Example 1	0.20	0.90	0.01	0.030	0.020	170.90
Inventive Example 2	0.16	0.90	0.01	0.030	0.020	148.06
Inventive Example 3	0.21	0.90	0.01	0.030	0.020	176.61
Inventive Example 4	0.20	0.78	0.01	0.030	0.020	163.34
Inventive Example 5	0.20	1.12	0.01	0.030	0.020	184.76
Comparative Example 1	0.14	0.90	0.01	0.030	0.020	136.64
Comparative Example 2	0.25	0.90	0.01	0.030	0.020	199.45
Comparative Example 3	0.20	0.60	0.01	0.030	0.020	152.00
Comparative Example 4	0.20	1.30	0.01	0.030	0.020	196.10
Comparative Example 5	0.20	0.90	0.03	0.030	0.020	170.90
Comparative Example 6	0.20	0.90	0.01	0.060	0.020	170.90
Comparative Example 7	0.20	0.90	0.01	0.030	0.075	170.90

[Table 2]

Remarks	Hot-rolled edge crack	Hot-rolled grain diameter (μm)	Hot-rolled carbide (area %)	Cold-rolled ferrite (area %)	Cold-rolled hard phase (area %)
Inventive Example 1	None	35	15	82.0	3.0
Inventive Example 2	None	35	12	85.3	2.7
Inventive Example 3	None	35	17	81.0	3.2
Inventive Example 4	None	35	15	82.2	2.8
Inventive Example 5	None	35	15	81.9	3.1
Comparative Example 1	None	35	12	85.5	2.5
Comparative Example 2	None	35	22	74.6	3.4
Comparative Example 3	None	35	15	82.2	2.8
Comparative Example 4	None	35	15	81.4	3.6
Comparative Example 5	None	28	15	82.0	3.0
Comparative Example 6	None	26	15	82.0	3.0
Comparative Example 7	Present	25	15	82.0	3.0

[Table 3]

Remarks	Yield Point (MPa)	Tensile Strength (MPa)	Elongation (%)	V-bending
Inventive Example 1	385	520	25	None
Inventive Example 2	345	490	32	None
Inventive Example 3	395	535	22	None
Inventive Example 4	355	500	30	None
Inventive Example 5	400	540	21	None
Comparative Example 1	310	430	37	None
Comparative Example 2	430	570	18	Present
Comparative Example 3	320	480	36	None
Comparative Example 4	440	580	17	Present
Comparative Example 5	395	540	23	Present
Comparative Example 6	390	525	24	Present
Comparative Example 7	385	523	26	None

[0081] As shown in Tables 1 to 3, it may be confirmed that desired mechanical properties may be obtained when the steel composition is appropriately adjusted. On the other hand, in Comparative Example 1, the C content is low, and it may be confirmed that the yield strength and tensile strength are low. In Comparative Example 2, the C content is high, cracks occur during the V-bending test, and it may be confirmed that the formability is poor. In Comparative Example 3, the Mn content is low, so it may be confirmed that the yield strength and tensile strength are low. In Comparative Example 4, the Mn content is high, cracks occur during the V-bending test, and it may be confirmed that the formability is poor. In Comparative Example 5, the P content is high, so cracks occurred during the V-bending test. In Comparative Example 6, the Al content is high, so cracks occurred during the V-bending test. In Comparative Example 7, since a large amount of Cu was included, edge cracks occurred in the hot-rolled steel sheet, and there was material loss because the portion where the edge cracks occurred was cut off and then cold rolling was performed.

Example 2

[0082] Using the steel grade summarized in the Inventive Example 1, a cold-rolled steel sheet was manufactured in the same manner as in Inventive Example 1, except that the conditions were partially changed to those summarized in Table 4 below.

[0083] High temperature compressive stress: After heating a slab at a heating rate of 20 °C/sec, maintaining the slab at 1200 °C for 3 minutes, and then cooling the slab at a cooling rate of 10 °C/sec, a compression test was performed at a temperature of 900 °C up to a strain of 1.2 to obtain a stress-strain curve, and the maximum stress value of the stress-strain curve was determined.

[Table 4]

Remarks	FDT(°C)	CT(°C)	Cold rolling reduction ratio (%)	Cold rolling annealing temperature (°C)	Cooling rate after annealing (°C/sec.)
Inventive Example 6	860	650	85	780	20
Inventive Example 7	900	620	85	780	20
Inventive Example 8	900	650	70	780	20
Inventive Example 9	900	650	85	760	20
Inventive Example 10	900	650	85	820	20
Inventive Example 11	900	650	85	780	35
Comparative Example 8	840	650	85	780	20

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(continued)

Remarks	FDT(°C)	CT(°C)	Cold rolling reduction ratio (%)	Cold rolling annealing temperature (°C)	Cooling rate after annealing (°C/sec.)
Comparative Example 9	900	600	85	780	20
Comparative Example 10	900	650	68	780	20
Comparative Example 11	900	650	85	730	20
Comparative Example 12	900	650	85	840	20
Comparative Example 13	900	650	85	780	40

[Table 5]

Remarks	High temperature compressive stress (MPa)	Hot-rolled edge crack	Hot-rolled grain diameter (μm)	Hot-rolled carbide (area %)	Cold-rolled ferrite (area %)	Cold-rolled hard phase (area %)
Inventive Example 6	170	None	25	14	97.0	3.0
Inventive Example 7	170	None	22	20	97.0	3.0
Inventive Example 8	130	None	25	15	99.0	1.0
Inventive Example 9	130	None	25	15	97.0	3.0
Inventive Example 10	130	None	25	15	97.0	3.0
Inventive Example 11	130	None	25	15	95.0	5.0
Comparative Example 8	220	None	15	27	97.0	3.0
Comparative Example 9	200	None	18	25	97.0	3.0
Comparative Example 10	130	None	25	15	97.0	3.0
Comparative Example 11	130	Present	25	15	40.0	60.0
Comparative Example 12	130	None	25	15	98.0	2.0
Comparative Example 13	130	Present	25	15	50.0	50.0

[Table 6]

Remarks	Yield Point (MPa)	Tensile Strength (MPa)	Elongation (%)	V-bending
Inventive Example 6	410	550	23	None
Inventive Example 7	410	550	23	None
Inventive Example 8	350	490	27	None
Inventive Example 9	415	555	21	None
Inventive Example 10	342	482	28	None
Inventive Example 11	420	560	20	None
Comparative Example 8	430	570	18	None
Comparative Example 9	430	570	17	None
Comparative Example 10	320	461	30	None
Comparative Example 11	480	620	14	Present
Comparative Example 12	320	461	30	None
Comparative Example 13	450	590	16	Present

[0084] As shown in Tables 4 to 6, it may be confirmed that desired mechanical properties may be obtained when the process conditions are appropriately adjusted. On the other hand, in Comparative Example 8, since the finishing rolling temperature is low, the high temperature compressive stress is high, and it may be confirmed that the elongation of the cold-rolled product after final annealing is inferior. In Comparative Example 9, since the coiling temperature is low, the high temperature compressive stress is high, and similarly, the fraction of carbides is high, so it may be confirmed that the elongation value after cold rolling decreases. In Comparative Example 10, the cold reduction ratio was low, and sufficient strength was not able to be secured. In Comparative Example 11, the annealing temperature is low, the ferrite fraction is small, and the fraction of the hard phase (bainite, martensite, and pearlite) increases, so it may be confirmed that formability decreases. In Comparative Example 12, the annealing temperature was high, and sufficient strength was not able to be secured. In Comparative Example 13, the cooling rate is fast, the ferrite fraction is small, and the fraction of the hard phase (bainite, martensite, and pearlite) increases, so it may be confirmed that formability decreases.

[0085] Figs. 1 and 2 show the microstructure of the hot-rolled steel sheet manufactured in Inventive Example 1 and the microstructure of the hot-rolled steel sheet manufactured in Comparative Example 8, respectively. It may be confirmed that in Inventive Example 1, the grain diameter of the hot-rolled steel sheet is coarse and carbides are finely dispersed and formed, whereas in Comparative Example 8, the grain diameter is refined and carbides are formed in clusters.

[0086] Figs. 3 and 4 show a photograph after a V-bending experiment on the cold-rolled steel sheet manufactured in Inventive Example 1 and a photograph after a V-bending experiment on the cold-rolled steel sheet manufactured in Comparative Example 4, respectively. In Inventive Example 1, cracks did not occur after the V-bending test, but in Comparative Example 4, it may be confirmed that cracks occurred on the TD surface.

[0087] The present invention is not limited to the above embodiments and/or examples, but may be manufactured in various different forms, and a person of ordinary skill in the art to which the present invention belongs will understand that the present invention may be implemented in other specific forms without changing the technical spirit or essential characteristics of the present invention. Therefore, it should be understood that the embodiments and/or examples described above are illustrative in all respects and not restrictive.

Claims

1. A cold-rolled steel sheet comprising, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities, wherein an area fraction of ferrite in the steel sheet is 80% or more.

2. The cold-rolled steel sheet of Claim 1,

wherein satisfies the following Equation 1.

[Equation 1]

$$571 \times [C] + 63 \times [Mn] \geq 140$$

(In Equation 1, [C] and [Mn] are the contents (wt%) of C and Mn, respectively.)

3. The cold-rolled steel sheet of Claim 1, further comprising at least one of Ti: 0.01 wt% or less and Nb: 0.01 wt% or less.

4. The cold-rolled steel sheet of Claim 1, wherein a sum of area fractions of bainite, martensite, and pearlite is 10% or less.

5. The cold-rolled steel sheet of Claim 1, wherein thickness of the steel sheet is 1.0 mm or less.

6. The cold-rolled steel sheet of Claim 1, wherein a crack is not formed in a bent portion during a bending test of the steel sheet under a load of 10 tons using a V-bending die having a radius of curvature of $r=0$.

7. The cold-rolled steel sheet of Claim 1,
wherein a yield strength is 340 MPa or more, a tensile strength is 450 MPa or more, and an elongation is 20% or more.

8. A method for manufacturing a cold-rolled steel comprising:

manufacturing a hot-rolled steel sheet by hot rolling a slab comprising, in wt%, carbon (C): 0.15 to 0.22%, manganese (Mn): 0.75 to 1.2%, phosphorus (P): 0.005 to 0.02%, copper (Cu): 0.005 to 0.07%, and aluminum (Al): 0.015 to 0.05%, with a balance of Fe and unavoidable impurities;

manufacturing a cold-rolled steel sheet by cold rolling the hot-rolled steel sheet; and
annealing the cold-rolled steel sheet,

wherein, in the step of manufacturing the hot-rolled steel sheet, finish rolling is completed at a temperature of 850 °C or higher, and coiling is performed at a temperature of 610 °C or higher,

wherein, in the step of manufacturing the cold-rolled steel sheet, a reduction ratio is 70% or more; and

wherein, in the annealing step, soaking is performed at 750 to 830 °C, and cooling is performed from the soaking temperature to 550 °C at a cooling rate of 35 °C/sec or less.

9. The method for manufacturing a cold-rolled steel of Claim 8,

further comprising a step of heating the slab at 1100 °C or higher for 150 minutes or more, before the step of manufacturing the hot-rolled steel sheet.

10. The method for manufacturing a cold-rolled steel of Claim 8,

wherein the slab has a maximum stress value of 180 MPa or less when a compression test is performed up to a strain of 1.2 at a temperature of 900 °C after heating at a heating rate of 20 °C/sec, maintaining the slab at 1200 °C for 3 minutes, and then cooling at a cooling rate of 10 °C/sec.

11. The method for manufacturing a cold-rolled steel of Claim 8,

wherein, in the step of manufacturing the hot-rolled steel sheet, rough rolling is finished at a temperature of 950 °C or higher.

12. The method for manufacturing a cold-rolled steel of Claim 8,

wherein, after the step of manufacturing the hot-rolled steel sheet, the average grain diameter of the hot-rolled steel sheet is 20 μm or more.

13. The method for manufacturing a cold-rolled steel of Claim 8,

wherein, after the step of manufacturing the hot-rolled steel sheet, the hot-rolled steel sheet comprises 20 area % or less of carbide.

14. A galvanized steel sheet, wherein a galvanized layer is present on a surface of the cold-rolled steel sheet according to any one of claims 1 to 7.

FIG. 1



FIG. 2

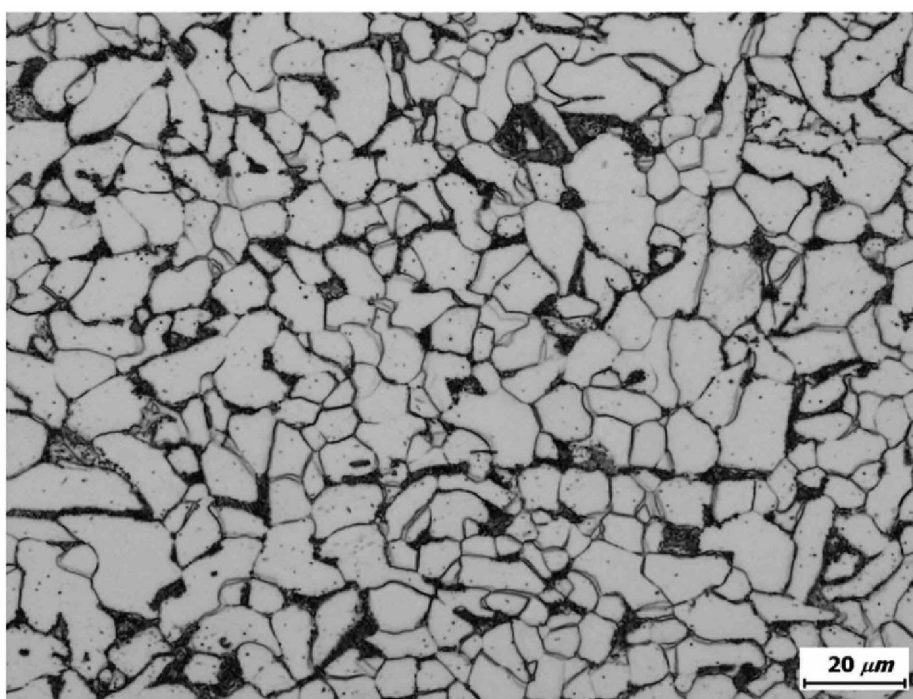


FIG. 3

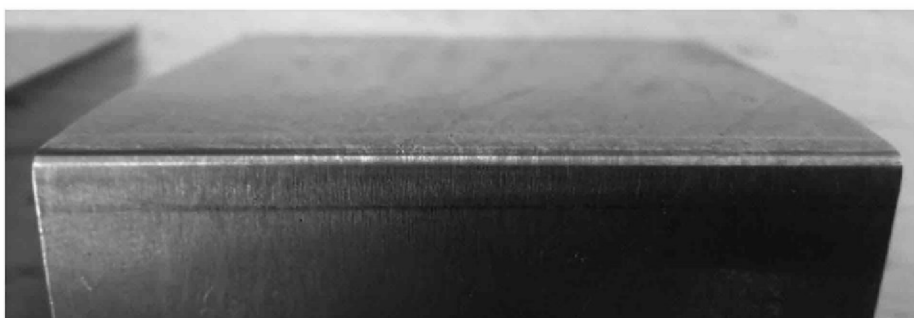
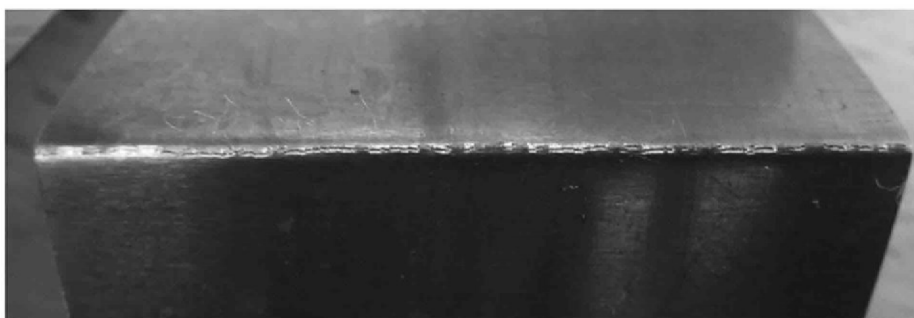


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063304

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; **C22C 38/16**(2006.01)i; **C22C 38/06**(2006.01)i; **C22C 38/14**(2006.01)i; **C22C 38/12**(2006.01)i;
C21D 8/02(2006.01)i; **C21D 9/46**(2006.01)i; **C23C 2/06**(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C 38/04(2006.01); B21B 1/26(2006.01); B32B 15/01(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01);
C22C 38/06(2006.01); C22C 38/58(2006.01); C23C 2/06(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: 냉연강판(cold rolled steel sheet), 페라이트(ferrite), 아연도금(zinc plating), 고강도
(high strength), 박물(thin)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 7311068 B1 (JFE STEEL K.K.) 19 July 2023 (2023-07-19) See paragraphs [0087], [0093] and [0095] and claims 1-2 and 12.	1-5,14 6-13
X	KR 10-2023-0013273 A (JFE STEEL CORPORATION) 26 January 2023 (2023-01-26) See claims 2-3 and 6.	1-5,14
A	US 2014-0335374 A1 (JFE STEEL CORPORATION) 13 November 2014 (2014-11-13) See claims 1-2 and 5-7.	1-14
A	KR 10-1570629 B1 (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORPORATION) 19 November 2015 (2015-11-19) See claims 1-3 and 6.	1-14

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

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“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

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Date of the actual completion of the international search 14 April 2025	Date of mailing of the international search report 14 April 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.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2024/063304

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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