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

(57) This cold-rolled steel sheet has a predetermined chemical composition, in which, in a case where a range of 1/8 to 3/8 of a sheet thickness from a surface in a sheet thickness direction is defined as a t/4 portion and a range of 20 μm from the surface in the sheet thickness direction is defined as a surface layer portion, a microstructure at the t/4 portion includes, by volume percentage, 0% or more and 10.0% or less of retained austenite and 90.0%

or more and 100% or less of one or two of martensite and tempered martensite, a ratio of a dislocation density of the surface layer portion to a dislocation density of the t/4 portion is 0.80 or more, a ratio of a hardness of the surface layer portion to a hardness of the t/4 portion is 0.90 or more, and a tensile strength of the cold-rolled steel sheet is 1,310 MPa or more.

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Description

[Technical Field of the Invention]

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

[0002] Priority is claimed on Japanese Patent Application No. 2021-120895, filed July 21, 2021, the content of which is incorporated herein by reference.

[Related Art]

[0003] Today, as industrial technology fields are highly divided, materials used in each technology field require special and advanced performance. For example, steel sheets for a vehicle are required to have high strength in order to improve fuel efficiency by reducing a weight of a vehicle body in consideration of the global environment. In a case where a high strength steel sheet is applied to the vehicle body of a vehicle, a desired strength can be imparted to the vehicle body while reducing a sheet thickness of the steel sheet and reducing the weight of the vehicle body.

[0004] In recent years, the demand for steel sheets for a vehicle has become more sophisticated, and among steel sheets for a vehicle, particularly for cold-rolled steel sheets used for vehicle body frame components, high strength is required, and a steel sheet having a tensile strength of 1,310 MPa or more is required.

[0005] In response to such a requirement, for example, Patent Document 1 discloses, as a high strength steel sheet used for a vehicle component or the like, a high strength steel sheet having a predetermined composition and having a predetermined steel sheet structure primarily containing martensite and bainite, in which an average number of inclusions having an average grain size of 5 μm or more in a cross section perpendicular to a rolling direction is 5.0 / mm^2 or less, and the high strength steel sheet has an excellent delayed fracture resistance property, and a tensile strength of 1,470 MPa or more.

[0006] In addition, Patent Document 2 discloses a thin steel sheet having a steel structure in which an area ratio of ferrite is 30% or less (including 0%), an area ratio of bainite is 5% or less (including 0%), and an area ratio of martensite and tempered martensite is 70% or more (including 100%), an area ratio of retained austenite is 2.0% or less (including 0%), a ratio of a dislocation density in a range of 0 to 20 μm from a surface of the steel sheet to a dislocation density of a sheet thickness center portion is 90% or more and 110% or less, and an average of the top 10% of cementite particle sizes from the surface of the steel sheet to a depth of 100 μm is 300 nm or less, in which a maximum warpage amount of the steel sheet when sheared at a length of 1 m in a longitudinal direction of the steel sheet is 15 mm or less. Patent Document 2 discloses that this thin steel sheet has a tensile strength of 980 MPa or more and can also obtain a tensile strength of 2,000 MPa or more.

[0007] In addition, Patent Document 3 discloses a high strength steel sheet in which a chemical composition (C, Si, Mn, Al, P, and S) satisfies a specified range, a remainder is iron and unavoidable impurities, and martensite occupies 95 area% or more in the entire structure, a structure from a position at a depth of 10 μm from a surface the steel sheet in a sheet thickness direction to a position at a 114 thickness depth satisfies a predetermined relation, and the steel sheet has a tensile strength of 1,180 MPa or more and an excellent delayed fracture resistance property.

[Prior Art Document]

[Patent Document]

[0008]

[Patent Document 1] Japanese Patent No. 6729835

[Patent Document 2] PCT International Publication No. WO2020/026838

[Patent Document 3] Japanese Unexamined Patent Application, First Publication No. 2013-104081

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0009] As described above, in the related art, high strength steel sheets having a tensile strength of 1,310 MPa or more have been proposed. In general, such high strength steel sheets include martensite and/or tempered martensite as a primary structure.

[0010] As a result of examination by the present inventors, it was found that in a high strength steel sheet including martensite or tempered martensite as a primary structure, in a case where a load that causes deformation is applied,

the steel sheet is left for a certain period of time after removing the load, and a load is applied again, a flow stress when the load is applied again is lower than a flow stress when the initial load is applied (hereinafter, sometimes simply described as a decrease in flow stress). However, in Patent Documents 1 to 3, no examination is conducted for a decrease in flow stress when the load is applied again, and there is room for improvement.

[0011] The present invention has been made in view of the above. An object of the present invention is to provide a cold-rolled steel sheet having a structure primarily including martensite and tempered martensite, and being capable of, in a case where a load is applied, the steel sheet is left for a certain period of time after removing the load, and a load is applied again, suppressing a decrease in a flow stress when the load is applied again from a flow stress when the initial load is applied (suppressing a decrease in flow stress).

[Means for Solving the Problem]

[0012] The present inventors examined the cause of the above-described decrease in the flow stress. As a result, it was found that even if a structure is martensite and/or tempered martensite throughout the entire sheet thickness direction, in a case where there is a difference in dislocation density in the structure depending on the position in the sheet thickness direction, the flow stress decreases.

[0013] In addition, as a result of further examinations by the present inventors, it was found that there are cases where the flow stress decreases even in a case where the difference in dislocation density at each position in the sheet thickness direction is small. The present inventors further examined the cause of this. As a result, it was found that even if the difference in dislocation density in the sheet thickness direction is small, the flow stress decreases in a case where dislocations are mainly mobile dislocations.

[0014] The present invention has been made in view of the above findings. The gist of the present invention is as follows.

[1] A cold-rolled steel sheet according to an aspect of the present invention includes, as a chemical composition, by mass%: C: 0.150% to 0.500%; Si: 0.01% to 2.00%; Mn: 0.50% to 3.00%; P: 0.0200% or less; S: 0.0200% or less; Al: 0.100% or less; N: 0.0200% or less; O: 0.020% or less; Ni: 0% to 1.000%; Mo: 0% to 1.000%; Cr: 0% to 2.000%; B: 0% to 0.010%; As: 0% to 0.050%; Co: 0% to 0.500%; Ti: 0% to 0.500%; Nb: 0% to 0.500%; V: 0% to 0.500%; Cu: 0% to 0.500%; W: 0% to 0.100%; Ta: 0% to 0.100%; Ca: 0% to 0.050%; Mg: 0% to 0.050%; La: 0% to 0.050%; Ce: 0% to 0.050%; Y: 0% to 0.050%; Zr: 0% to 0.050%; Sb: 0% to 0.050%; Sn: 0% to 0.050%; and a remainder: Fe and impurities, in which, in a case where a range of 1/8 to 3/8 of a sheet thickness from a surface in a sheet thickness direction is defined as a t/4 portion and a range of 20 μ m from the surface in the sheet thickness direction is defined as a surface layer portion, a microstructure at the t/4 portion includes, by volume percentage, 0% or more and 10.0% or less of retained austenite and 90.0% or more and 100% or less of one or two of martensite and tempered martensite, a ratio of a dislocation density of the surface layer portion to a dislocation density of the t/4 portion is 0.80 or more, a ratio of a hardness of the surface layer portion to a hardness of the t/4 portion is 0.90 or more, and a tensile strength of the cold-rolled steel sheet is 1,310 MPa or more.

[2] In the cold-rolled steel sheet according to [1], a coating layer made of zinc, aluminum, or magnesium, or an alloy of one or more of these metals may be provided on the surface.

[3] A manufacturing method of a cold-rolled steel sheet according to another aspect of the present invention includes: a hot rolling process of performing hot rolling on a slab having the chemical composition according to [1] to obtain a hot-rolled steel sheet, and coiling the hot-rolled steel sheet in a state in which a temperature of a center portion in a width direction is higher than 600°C and 700°C or lower and a temperature of an edge portion at a position 20 mm away from an end portion in the width direction is 600°C or lower; a cold rolling process of pickling the hot-rolled steel sheet after the hot rolling process and performing cold rolling on the hot-rolled steel sheet at a rolling reduction of 30% to 90% to obtain a cold-rolled steel sheet; an annealing process of heating the cold-rolled steel sheet to an annealing temperature of higher than Ac3°C, holding the cold-rolled steel sheet at the annealing temperature, and cooling the cold-rolled steel sheet after the holding to a cooling stop temperature so that an average cooling rate to 400°C is 10 °C/sec or faster and an average cooling rate from 400°C to the cooling stop temperature of 100°C or lower is 15 °C/sec or faster; a heat treatment process of heating the cold-rolled steel sheet after the annealing process to a temperature range of 200°C to 350°C and holding the cold-rolled steel sheet in the temperature range; and a skin pass rolling process of performing skin pass rolling on the cold-rolled steel sheet after the heat treatment process at a rolling reduction of 0.1% or more, in which a difference between a sheet thickness of the center portion in the width direction and a sheet thickness of the edge portion of the cold-rolled steel sheet after the cold rolling process is 10 μ m or more.

[4] In the manufacturing method of a cold-rolled steel sheet according to [3], in the annealing process, a coating layer made of zinc, aluminum, or magnesium, or an alloy of one or more of these metals may be formed on front and rear surfaces of the cold-rolled steel sheet.

[Effects of the Invention]

[0015] According to the above aspects of the present invention, it is possible to provide a cold-rolled steel sheet having a structure primarily including martensite and tempered martensite, and being capable of, in a case where a load is applied, the steel sheet is left for a certain period of time after removing the load, and a load is applied again, suppressing a decrease in a flow stress when the load is applied again from a flow stress when the initial load is applied, and a manufacturing method thereof.

[Embodiments of the Invention]

[0016] A cold-rolled steel sheet according to an embodiment of the present invention (a cold-rolled steel sheet according to the present embodiment) and a manufacturing method for obtaining the cold-rolled steel sheet will be described.

[0017] The cold-rolled steel sheet according to the present embodiment has a predetermined chemical composition, in which, in a case where a range of 1/8 to 3/8 of a sheet thickness from a surface in a sheet thickness direction is defined as a t/4 portion and a range of 20 μm from the surface in the sheet thickness direction is defined as a surface layer portion, a microstructure (metallographic structure) at the t/4 portion includes, by volume percentage, 0% or more and 10.0% or less of retained austenite and 90.0% or more and 100% or less of one or two of martensite and tempered martensite, a ratio of a dislocation density of the surface layer portion to a dislocation density of the t/4 portion is 0.80 or more, and a ratio of a hardness of the surface layer portion to a hardness of the t/4 portion is 0.90 or more. In addition, a tensile strength of the cold-rolled steel sheet is 1,310 MPa or more.

[0018] Hereinafter, each will be described.

[0019] In the description, a range indicated with "to" in between includes, in principle, the values at both ends of the range as a lower limit and an upper limit. However, numerical values indicated as "more than" or "less than" are not included in the range.

[Chemical Composition]

[0020] First, the chemical composition will be described.

[0021] In the present embodiment, % of an amount of each element means mass%.

C: 0.150% to 0.500%

[0022] C is related to a hardness of martensite and tempered martensite and is an element necessary for increasing a strength of the steel sheet. In order to obtain a tensile strength of 1,310 MPa or more, a C content needs to be at least 0.150% or more. Therefore, the C content is set to 0.150% or more. The C content is preferably 0.180% or more, and more preferably 0.200% or more.

[0023] On the other hand, when the C content is more than 0.500%, weldability deteriorates and formability deteriorates. Therefore, the C content is set to 0.500% or less. The C content is preferably 0.350% or less, and more preferably 0.300% or less.

Si: 0.01% to 2.00%

[0024] Si is a solid solution strengthening element and is an effective element for high-strengthening of the steel sheet. In order to obtain this effect, a Si content is set to 0.01% or more. The Si content is set to preferably 0.10% or more, and more preferably 0.20% or more.

[0025] On the other hand, when the Si content is excessive, the formability decreases, and wettability to a plating decreases. Therefore, the Si content is set to 2.00% or less. Therefore, the Si content is set to preferably 1.80% or less and more preferably 1.70% or less.

Mn: 0.50% to 3.00%

[0026] Mn is an element that improves hardenability and is an element that promotes the generation of martensite. When a Mn content is less than 0.50%, it becomes difficult to obtain a target microstructure. Therefore, the Mn content is set to 0.50% or more.

[0027] On the other hand, when the Mn content is excessive, the effect of improving the hardenability is reduced due to segregation of Mn, and a material cost increases. Therefore, the Mn content is set to 3.00% or less. The Mn content is preferably 2.80% or less.

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P: 0.0200% or Less

[0028] P is an element contained in steel as an impurity and is an element that segregates at grain boundaries and embrittles steel. Therefore, a P content is preferably as small as possible and may be 0%. However, in consideration of a time and a cost for removing P, the P content is set to 0.0200% or less. The P content is preferably 0.0150% or less, and more preferably 0.0100% or less.

[0029] From the viewpoint of a refining cost or the like, the P content may be set to 0.0001% or more.

S: 0.0200% or Less

[0030] S is an element contained in steel as an impurity and is an element that forms sulfide-based inclusions and deteriorates the formability of the steel sheet. Therefore, a S content is preferably as small as possible and may be 0%. However, in consideration of a time and a cost for removing S, the S content is set to 0.0200% or less. The S content is preferably 0.0100% or less, more preferably 0.0050% or less, and even more preferably 0.0030% or less.

[0031] From the viewpoint of a refining cost or the like, the S content may be set to 0.0001% or more.

Al: 0.100% or Less

[0032] Al is an element having an action of deoxidizing molten steel. In the cold-rolled steel sheet according to the present embodiment, Al does not necessarily have to be contained, and an Al content may be 0%. However, Al may be contained for the purpose of deoxidation. Therefore, the Al content is preferably set to 0.001% or more. Al has an action of enhancing the stability of austenite like Si, and thus may be contained in order to obtain retained austenite.

[0033] On the other hand, when the Al content is too high, not only surface defects caused by alumina are likely to occur, but also a transformation point significantly increases, so that a volume percentage of ferrite increases. In this case, it becomes difficult to obtain a desired metallographic structure, and a sufficient tensile strength cannot be obtained. Therefore, the Al content is set to 0.100% or less. The Al content is preferably 0.050% or less, more preferably 0.040% or less, and even more preferably 0.030% or less.

N: 0.0200% or Less

[0034] N is an element that can be contained in steel as an impurity and is an element that forms coarse precipitates and deteriorates the formability. Therefore, a N content is set to 0.0200% or less. The N content is preferably 0.0100% or less, and more preferably 0.0060% or less. The N content is preferably as small as possible and may be 0%. However, from the viewpoint of a refining cost or the like, the N content may be set to 0.0001% or more.

O: 0.020% or Less

[0035] O is an element that is contained as an impurity. When an O content is more than 0.020%, coarse oxides are formed in steel, and the formability decreases. Therefore, the O content is set to 0.020% or less. The O content is set to preferably 0.010% or less, and more preferably 0.005% or less. The O content may be 0%. However, from the viewpoint of refining cost or the like, the O content may be set to 0.0001% or more or 0.001% or more.

[0036] In the chemical composition of the cold-rolled steel sheet according to the present embodiment, the remainder excluding the above elements is basically Fe and impurities. The impurities are incorporated from steel raw materials and/or in a steelmaking process and are elements that are allowed to be present in a range in which the characteristics of the cold-rolled steel sheet according to the present embodiment are not clearly deteriorated.

[0037] On the other hand, for the purpose of improving various properties, the chemical composition of the cold-rolled steel sheet according to the present embodiment may contain, instead of a portion of Fe, one or two or more selected from the group consisting of Ni, Mo, Cr, B, As, Co, Ti, Nb, V, Cu, W, Ta, Ca, Mg, La, Ce, Y, Zr, Sb, and Sn in the following ranges. Since these elements may not be contained, lower limits thereof are 0%. In addition, even if these elements are contained as impurities, the effects of the cold-rolled steel sheet according to the present embodiment are not impaired as long as the amounts of the elements are within the ranges described below.

[0038]

Ni: 0% to 1.000%

Mo: 0% to 1.000%

Cr: 0% to 2.000%

B: 0% to 0.010%

As: 0% to 0.050%

[0039] Ni, Mo, Cr, B, and As are elements that improve the hardenability and contribute to the high-strengthening of the steel sheet. Therefore, these elements may be contained. In order to sufficiently obtain the above effects, it is preferable that a Ni content, a Mo content, and a Cr content are set to 0.010% or more, a B content is set to 0.0001% or more, and/or an As content is set to 0.001% or more. More preferably, the Ni content, the Mo content, and the Cr content are 0.050% or more, the B content is 0.001% or more, and the As content is 0.005% or more. It is not essential to obtain the above effects. Therefore, it is not necessary to particularly limit lower limits of the Ni content, the Mo content, the Cr content, the B content, and the As content, and the lower limits thereof are 0%.

[0040] On the other hand, even if these elements are excessively contained, the effect of the above-described action is saturated, which is uneconomical. Therefore, in a case where these elements are contained, the Ni content and the Mo content are set to 1.000% or less, the Cr content is set to 2.000% or less, the B content is set to 0.010% or less, and the As content is set to 0.050% or less. The Ni content and the Mo content are each preferably 0.500% or less, the Cr content is preferably 1.000% or less, the B content is preferably 0.0060% or less, and the As content is 0.030% or less.

Co: 0% to 0.500%

[0041] Co is an element effective in improving the strength of the steel sheet. A Co content may be 0%. However, in order to obtain the above effect, the Co content is preferably 0.010% or more, and more preferably 0.100% or more.

[0042] On the other hand, when the Co content is too high, there is a concern that elongation of the steel sheet decreases and the formability decreases. Therefore, the Co content is set to 0.500% or less.

[0043]

Ti: 0% to 0.500%

Nb: 0% to 0.500%

V: 0% to 0.500%

Cu: 0% to 0.500%

W: 0% to 0.100%

Ta: 0% to 0.100%

[0044] Ti, Nb, V, Cu, W, and Ta are elements having an action of improving the strength of the steel sheet by precipitation hardening. Therefore, these elements may be contained. In order to sufficiently obtain the above effect, it is preferable that one or more of Ti, Nb, V, Cu, W, and Ta are contained and the amount of each element is 0.001% or more.

[0045] On the other hand, when these elements are excessively contained, a recrystallization temperature rises, the metallographic structure of the cold-rolled steel sheet becomes non-uniform, and the formability is impaired. Therefore, the Ti content, the Nb content, the V content, and the Cu content are each set to 0.500% or less. In addition, the W content and the Ta content are each set to 0.100% or less.

[0046]

Ca: 0% to 0.050%

Mg: 0% to 0.050%

La: 0% to 0.050%

Ce: 0% to 0.050%

Y: 0% to 0.050%

Zr: 0% to 0.050%

Sb: 0% to 0.050%

[0047] Ca, Mg, La, Ce, Y, Zr, and Sb are elements that contribute to the fine dispersion of inclusions in steel, and are elements that contribute to the improvement of the formability of the steel sheet by this fine dispersion. Therefore, these elements may be contained. In order to obtain the above effects, it is preferable that one or more of Ca, Mg, La, Ce, Y, Zr, and Sb are contained and the amount of each element is set to 0.001% or more.

[0048] On the other hand, when these elements are excessively contained, ductility deteriorates. Therefore, the amounts of Ca, Mg, La, Ce, Y, Zr, and Sb are each set to 0.050% or less.

Sn: 0% to 0.050%

[0049] Sn is an element that suppresses the coarsening of grains and contributes to the improvement in the strength of the steel sheet. Therefore, Sn may be contained.

[0050] On the other hand, Sn is an element that may cause a decrease in cold formability of the steel sheet attributed to the embrittlement of ferrite. When a Sn content is more than 0.050%, adverse effects become significant. Therefore,

the Sn content is set to 0.050% or less. The Sn content is preferably 0.040% or less.

[0051] The chemical composition of the cold-rolled steel sheet according to the present embodiment can be obtained by the following method.

[0052] For example, the chemical composition may be measured using inductively coupled plasma-atomic emission spectrometry (ICP-AES) for chips according to JIS G 1201 (2014). In this case, the chemical composition is an average content in the entire sheet thickness. For the elements which cannot be measured by ICP-AES, C and S may be measured using a combustion-infrared absorption method, N may be measured using an inert gas fusion-thermal conductivity method, and O may be measured using an inert gas fusion-non-dispersive infrared absorption method.

[0053] In a case where the steel sheet is provided with a coating layer on the surface, the chemical composition may be analyzed after removing the coating layer by mechanical grinding or the like. In a case where the coating layer is a plating layer, the coating layer may be removed by dissolving the plating layer in an acid solution containing an inhibitor that suppresses the corrosion of the steel sheet.

[Microstructure (Metallographic Structure)]

[0054] In the present embodiment, a range of a 1/8 thickness position to a 3/8 thickness position from the surface centered at a 1/4 thickness position from the surface in the sheet thickness direction will be described as a t/4 portion ((1/4)t portion), and a range from the surface to 20 μm in the sheet thickness direction will be described as a surface layer portion.

[Microstructure of t/4 Portion: by Volume Percentage, 0% or More and 10.0% or Less of Retained Austenite and 90.0% or More and 100% or Less of One or Two of Martensite and Tempered Martensite Are Contained]

[0055] Retained austenite contributes to the improvement in the formability of the steel sheet by improving uniform elongation of the steel sheet through a TRIP effect. Therefore, retained austenite (retained γ) may be contained. In a case of obtaining the above effect, the volume percentage of retained austenite is preferably set to 1.0% or more. The volume percentage of retained austenite is more preferably 2.0% or more, and even more preferably 3.0% or more.

[0056] On the other hand, when the volume percentage of retained austenite is excessive, a grain size of retained austenite increases. Such retained austenite having a large grain size becomes coarse and hard martensite after deformation. In this case, the origin of cracks is likely to occur, and the formability decreases. Therefore, the volume percentage of retained austenite is set to 10.0% or less. The volume percentage of retained austenite is preferably 8.0% or less, and more preferably 7.0% or less.

[0057] As a structure other than retained austenite, one or two of martensite and tempered martensite are contained.

[0058] Martensite (so-called fresh martensite) and tempered martensite are aggregates of lath-shaped grains and greatly contribute to the improvement in strength. Therefore, the cold-rolled steel sheet according to the present embodiment contains martensite and tempered martensite in a total volume percentage of 90.0% to 100%.

[0059] Unlike martensite, tempered martensite is a hard structure containing fine iron-based carbides inside by tempering. Tempered martensite is a structure that contributes less to the improvement in strength than martensite but is not brittle and has ductility. Therefore, in a case where it is desired to further increase the formability, it is preferable to increase the volume percentage of tempered martensite. For example, the volume percentage of tempered martensite is 85.0% or more.

[0060] On the other hand, in a case where it is desired to obtain high strength, it is preferable to increase the volume percentage of martensite.

[0061] The microstructure may contain bainite in addition to retained austenite, martensite, and tempered martensite. It is preferable that ferrite and pearlite are not contained.

[0062] The volume percentage of each structure in the microstructure of the t/4 portion of the cold-rolled steel sheet according to the present embodiment is measured as follows.

[0063] That is, the volume percentages of ferrite, bainite, martensite, tempered martensite, and pearlite are obtained by collecting a test piece from an arbitrary position in a rolling direction and in a width direction of the steel sheet, polishing a longitudinal section parallel to the rolling direction (cross section parallel to the sheet thickness direction), and observing a structure revealed by Nital etching in the range (t/4 portion) of 1/8 to 3/8 of the sheet thickness from the surface using a scanning electron microscope (SEM). In the SEM observation, five visual fields of 30 μm $\times$ 50 μm are observed at a magnification of 3,000-fold, area ratios of each structure are measured from the observed images, and an average value thereof is calculated. Since there is no microstructural change in a direction (steel sheet width direction) perpendicular to the rolling direction and area ratios of the longitudinal section parallel to the rolling direction are equal to volume percentages, the area ratios obtained by the microstructural observation are each used as volume percentages.

[0064] In the measurement of the area ratio of each structure, a region with no substructure revealed and a low luminance is defined as ferrite. In addition, a region with no substructure revealed and a high luminance is defined as

martensite or retained austenite. In addition, a region in which a substructure is revealed is defined as tempered martensite or bainite.

[0065] Bainite and tempered martensite can be distinguished from each other by further carefully observing carbides in grains.

[0066] Specifically, tempered martensite includes martensite laths and cementite generated within the laths. Here, since there are two or more kinds of crystal orientation relationships between martensite laths and cementite, cementite included in the tempered martensite has a plurality of variants. On the other hand, bainite is classified into upper bainite and lower bainite. Upper bainite includes lath-shaped bainitic ferrite and cementite generated at the interface between the laths and can be easily distinguished from tempered martensite. Lower bainite includes lath-shaped bainitic ferrite and cementite generated within the laths. Here, there is one kind of crystal orientation relationship between bainitic ferrite and cementite unlike tempered martensite, and cementite included in lower bainite has the same variant. Therefore, lower bainite and tempered martensite can be distinguished from each other on the basis of the variants of cementite.

[0067] On the other hand, martensite and retained austenite cannot be clearly distinguished from each other by the SEM observation. Therefore, the volume percentage of martensite is calculated by subtracting the volume percentage of retained austenite calculated by a method described later from a volume percentage of a structure determined to be martensite or retained austenite.

[0068] The volume percentage of retained austenite is obtained as described below: a test piece is collected from an arbitrary position in the steel sheet, a rolled surface is chemically polished from the surface of the steel sheet to a 114 thickness position, and the volume percentage of retained austenite is quantified from integrated intensities of (200) and (210) planes of ferrite and integrated intensities of (200), (220), and (311) planes of austenite by $\text{MoK}\alpha$ radiation.

[Ratio of Dislocation Density of Surface Layer Portion to Dislocation Density of t/4 Portion: 0.80 or More]

[0069] In the cold-rolled steel sheet according to the present embodiment, the microstructure primarily includes martensite and/or tempered martensite obtained by tempering martensite.

[0070] Martensite can be obtained by holding the steel sheet in an austenite single phase region and then rapidly cooling the steel sheet. However, in a case where cooling is performed by a general method, martensite has a difference in structural characteristics (for example, dislocation density contained) depending on the position in the steel sheet in the sheet thickness direction. This difference is attributed to a difference in timing of transformation. That is, during cooling, a temperature of a region close to the surface of the steel sheet first decreases, and then a temperature inside the steel sheet decreases. Therefore, the transformation from austenite to martensite occurs first on a surface layer side of the steel sheet. Since the martensitic transformation is an exothermic reaction, the martensite generated on the surface layer side is held at a high temperature for a longer period of time than the martensite inside, and undergoes tempering. The tempering causes a decrease in dislocation density in martensite.

[0071] When such a difference in dislocation density is present, in a case where a load that causes deformation is applied, the steel sheet is left for a certain period of time after removing the load, and a load is applied again, a flow stress when the load is applied again is lower than a flow stress when the initial load is applied. Therefore, in the cold-rolled steel sheet according to the present embodiment, the ratio ($\rho_s/\rho_{t/4}$) of the dislocation density (ρ_s) of the surface layer portion to the dislocation density ($\rho_{t/4}$) of the t/4 portion is set to 0.80 or more. ($\rho_s/\rho_{t/4}$) is preferably 0.85 or more, and more preferably 0.90 or more.

[0072] The dislocation density of the t/4 portion is preferably $5.2 \times 10^{15} \text{ M}^{-2}$ or more. Therefore, in consideration of a preferable range of $\rho_s/\rho_{t/4}$, the dislocation density of the surface layer portion is preferably $4.2 \times 10^{15} \text{ M}^{-2}$ or more.

[0073] The dislocation density at each position is obtained by the following method.

[0074] Considering that a position 20 μm away from the surface of the steel sheet is a representative structure of the surface layer portion and a 114 thickness position from the surface is a representative structure of the 114 portion, a sample obtained by grinding 20 μm from the surface and a sample obtained by grinding 114 of the sheet thickness from the surface are prepared, strain is removed by performing chemical polishing on each ground surface, and then X-ray diffraction is performed. A dislocation density at the position 20 μm away from the surface and a dislocation density at the 114 thickness position from the surface are obtained from an X-ray diffraction profile obtained by the X-ray diffraction using a modified Williamson-Hall method and a modified Warren-Averbach method. Specifically, the dislocation density is obtained according to a method described in ISIJ Int. vol. 50 (2010) p. 875-882. The dislocation density at the position 20 μm away from the surface is defined as the dislocation density of the surface layer portion, and the dislocation density at the 114 thickness position from the surface is defined as the dislocation density of the 114 portion.

[Ratio of Hardness of Surface Layer Portion to Hardness of t/4 Portion: 0.90 or More]

[0075] As described above, even if the difference in dislocation density in the sheet thickness direction is small, when the dislocation is mainly a mobile dislocation, in a case where a load that causes deformation is applied, the steel sheet

is left for a certain period of time after removing the load, and a load is applied again, a flow stress when the load is applied again is lower than a flow stress when the initial load is applied.

[0076] Therefore, in the cold-rolled steel sheet according to the present embodiment, dislocations in the surface layer portion are particularly immobilized. In the present embodiment, the ratio of the hardness of the surface layer portion to the hardness of the t/4 portion is used as an index of whether or not dislocations are immobilized.

[0077] In a case where ($\rho_s/\rho_{t/4}$) is 0.80 or more and the ratio of the hardness of the surface layer portion to the hardness of the t/4 portion is 0.90 or more, dislocations are immobilized, and a decrease in the flow stress can be prevented. The ratio of the hardness is preferably 0.92 or more, more preferably 0.94 or more, and even more preferably 0.95 or more.

[0078] Immobilization of dislocations can be achieved by performing skin pass rolling on a steel sheet with an intentionally provided difference in sheet thickness, which will be described later.

[0079] Since there is a correlation between the tensile strength and the hardness, the hardness of the t/4 portion is preferably 360 Hv or more. Therefore, in consideration of a preferable range of the ratio of the hardness of the surface layer portion to the hardness of the t/4 portion, the hardness of the surface layer portion is preferably 324 Hv or more.

[0080] The hardness is obtained by the following method.

[0081] A cut surface perpendicular to the rolling direction of the steel sheet and parallel to the sheet thickness direction is formed and mirror-polished. Subsequently, Vickers hardness measurement is performed at four points each at the position 20 μm away from the surface of the steel sheet and at the 1/4 thickness position from the surface on the cut surface based on JIS Z 2244-1 (2020). A load in the Vickers hardness measurement is set to 2 kgf. An average value of hardness measurement values at the position 20 μm away from the surface of the steel sheet is defined as the hardness of the surface layer portion, and an average value of hardness measurement values at the 1/4 thickness position from the surface is defined as the hardness of the t/4 portion.

[0082] The cold-rolled steel sheet according to the present embodiment may have, on the surface (one or both), zinc, aluminum, or magnesium, or an alloy of one or more of these metals, or coating layer made of zinc, aluminum, or magnesium, or an alloy of one or more of these metals (Containing of impurities and the like are permitted).

[0083] Corrosion resistance is improved by providing the coating layer on the surface. When there is a concern about holes due to corrosion in a steel sheet for a vehicle, there are cases where the steel sheet cannot be thinned to a certain sheet thickness or less even if the high-strengthening is achieved. One of the purposes of the high-strengthening of the steel sheet is to reduce the weight by thinning. Therefore, even if a high strength steel sheet is developed, an application range of a steel sheet with low corrosion resistance is limited. As a method for solving these problems, it is conceivable to form a coating layer on the surface in order to improve corrosion resistance.

[0084] The coating layer is, for example, a hot-dip galvanized layer, a hot-dip galvanized layer, an electrogalvanized layer, an aluminum plating layer, a Zn-Al alloy plating layer, an Al-Mg alloy plating layer, or a Zn-Al-Mg alloy plating layer.

[0085] In a case where the surface has a coating layer, a surface used as a reference for the t/4 portion and the like described above is a surface of base metal excluding the coating layer.

[Tensile Strength]

[0086] In the cold-rolled steel sheet according to the present embodiment, an object is to achieve a tensile strength (TS) of 1,310 MPa or more as a strength that contributes to a reduction in weight of a vehicle body of a vehicle. From the viewpoint of an impact absorption property, the tensile strength of the steel sheet is preferably 1,400 MPa or more and more preferably 1,470 MPa or more.

[0087] It is not necessary to limit an upper limit of the tensile strength. However, there are cases where an increase in the tensile strength causes a decrease in formability. Therefore, the tensile strength may be set to 2,000 MPa or less.

<Manufacturing Method>

[0088] The cold-rolled steel sheet according to the present embodiment can be stably manufactured according to the following manufacturing method, although the effects can be obtained as long as the cold-rolled steel sheet has the above-described characteristics regardless of the manufacturing method.

[0089] Specifically, the cold-rolled steel sheet according to the present embodiment can be manufactured by a manufacturing method including the following steps (I) to (VI):

(I) a hot rolling step of performing hot rolling on a slab having a predetermined chemical composition to obtain a hot-rolled steel sheet, and coiling the hot-rolled steel sheet in a state in which a temperature of a center portion in a width direction is higher than 600°C and 700°C or lower and a temperature of an edge portion at a position 20 mm away from an end portion in the width direction is 600°C or lower;

(III) a cold rolling step of pickling the hot-rolled steel sheet after the hot rolling step and performing cold rolling on the hot-rolled steel sheet at a rolling reduction of 30% to 90% to obtain a cold-rolled steel sheet;

(IV) an annealing step of heating the cold-rolled steel sheet to an annealing temperature of higher than $Ac3^{\circ}C$, holding the cold-rolled steel sheet at the annealing temperature, and cooling the cold-rolled steel sheet after the holding to a cooling stop temperature so that an average cooling rate to $400^{\circ}C$ is $10^{\circ}C/sec$ or faster and an average cooling rate from $400^{\circ}C$ to the cooling stop temperature of $100^{\circ}C$ or lower is $15^{\circ}C/sec$ or faster;

(V) a heat treatment step of heating the cold-rolled steel sheet after the annealing step to a temperature range of $200^{\circ}C$ to $350^{\circ}C$ and holding the cold-rolled steel sheet in the temperature range; and

(VI) a skin pass rolling step of performing skin pass rolling on the cold-rolled steel sheet after the heat treatment step at a rolling reduction of 0.1% or more.

[0090] In addition, in the manufacturing method of the cold-rolled steel sheet according to the present embodiment, a difference between a sheet thickness of the center portion in the width direction and a sheet thickness of the edge portion of the cold-rolled steel sheet after the cold rolling step is set to $10\ \mu m$ or more.

[0091] Hereinafter, each step will be described.

[Hot Rolling Step]

[0092] In the hot rolling step, a slab having the same chemical composition as the cold-rolled steel sheet according to the present embodiment is hot-rolled to obtain a hot-rolled steel sheet. The hot rolling is preferably performed under conditions in which a finish rolling completion temperature is $Ac3^{\circ}C$ or higher in order to satisfy the temperature at the time of coiling, which will be described later. An upper limit of the finish rolling completion temperature is not particularly limited, but is generally $950^{\circ}C$ or lower.

[0093] This hot-rolled steel sheet is coiled in a state in which the temperature of the center portion in the width direction is higher than $600^{\circ}C$ and $700^{\circ}C$ or lower and the temperature of the edge portion at the position 20 mm from the end portion in the width direction is $600^{\circ}C$ or lower.

[0094] In order to cause a coiling temperature of the edge portion to be lower than that of the center portion in the width direction, the edge portion is cooled at a cooling rate faster than that of the center portion. For example, in a case where only the edge portion of the steel sheet after hot rolling is subjected to water cooling or the entire steel sheet is subjected to water cooling, the amount of cooling water for the edge portion may be set to be larger than that for the center portion in the width direction.

[0095] After the edge portion is subjected to water cooling, the edge portion is tempered by heat transfer from the center portion in the width direction with a higher temperature during the coiling and thus becomes softer than the center portion in the width direction. As a result, in a state of being cooled to near room temperature, a strength of the edge portion is lower than a strength of the center portion in the width direction.

[0096] By performing cold rolling, which will be described later, on the steel sheet having such a difference in strength in the width direction, a difference in sheet thickness occurs between the center portion in the width direction and the edge portion of the steel sheet.

[0097] When the coiling temperature of the center portion in the width direction is higher than $700^{\circ}C$, the center portion in the width direction is softened. In addition, when the coiling temperature of the center portion in the width direction is $600^{\circ}C$ or lower, difference in temperature from the edge portion becomes small, or the edge portion cannot be sufficiently tempered. The coiling temperature of the center portion is preferably $620^{\circ}C$ or higher.

[0098] In addition, when the coiling temperature of the edge portion is higher than $600^{\circ}C$, a softening effect by the tempering cannot be sufficiently obtained. In addition, when the coiling temperature of the edge portion is $400^{\circ}C$ or lower, tempering is performed by heat transfer from the center portion in the width direction. However, due to an increase in strength, a cold rolling load increases, and cracks occur in some cases. Therefore, the coiling temperature of the edge portion is preferably higher than $400^{\circ}C$, and more preferably $450^{\circ}C$ or higher.

[0099] In a case where the difference in sheet thickness between the center portion in the width direction and the edge portion is further increased, a difference in coiling temperature between the center portion in the width direction and the edge portion is preferably $50^{\circ}C$ or higher, more preferably $75^{\circ}C$ or higher, and even more preferably $100^{\circ}C$ or higher.

[0100] A manufacturing method of the slab that is subjected to the hot rolling is not particularly limited. In a preferable manufacturing method of the slab taken as an example, a steel having the above-described chemical composition is melted by a known method, thereafter made into a steel ingot by a continuous casting method, or made into a steel ingot by any casting method, and then made into a steel piece by a blooming method or the like. In a continuous casting step, in order to suppress the occurrence of surface defects due to inclusions, it is preferable to cause an external additional flow such as electromagnetic stirring to occur in molten steel in a mold. The steel ingot or steel piece may be reheated after being cooled once and subjected to hot rolling, or the steel ingot in a high temperature state after the continuous casting or the steel piece in a high temperature state after the blooming may be subjected to hot rolling as it is, after being kept hot, or after being subjected to auxiliary heating. In the present embodiment, the steel ingot and the steel piece are collectively referred to as a "slab" as a material of hot rolling.

[Cold Rolling Step]

[0101] In the cold rolling step, the hot-rolled steel sheet after the hot rolling step is pickled and cold-rolled at a rolling reduction of 30% to 90% to obtain a cold-rolled steel sheet.

[0102] Pickling conditions are not particularly limited and may be known conditions.

[0103] In the cold rolling step, by performing cold rolling on the steel sheet having a difference in strength in the width direction, a steel sheet (cold-rolled steel sheet) having a difference in sheet thickness in the width direction is obtained.

[0104] When the rolling reduction (cumulative rolling reduction) during the cold rolling is less than 30%, a sufficient difference in sheet thickness cannot be provided. In addition, when the rolling reduction during the cold rolling is more than 90%, a cold rolling load becomes too large, which makes cold rolling difficult.

[0105] In the manufacturing method of the cold-rolled steel sheet according to the present embodiment, with the hot rolling step and the cold rolling step performed as described above, the cold-rolled steel sheet in which the difference between the sheet thickness of the center portion in the width direction of the cold-rolled steel sheet and the sheet thickness of the edge portion is 10 μm or more after the cold rolling step can be obtained. The difference in sheet thickness is preferably 15 μm or more.

[0106] An upper limit of the difference in sheet thickness is not limited. However, when the difference in sheet thickness is large, there are cases where cracks are initiated from a portion with a small sheet thickness and hole expansibility decreases. Therefore, from the viewpoint of formability, the difference in sheet thickness may be set to 55 μm or less.

[0107] The sheet thickness of the center portion in the width direction and the sheet thickness of the edge portion can be measured by installing a scanning sheet thickness meter on an outlet side of a cold rolling mill.

[Width Trimming Step]

[0108] Width trimming may be performed to cut off any width from the end portion in the width direction of the steel sheet as long as the difference between the sheet thickness of the center portion in the width direction and the sheet thickness of the edge portion is 10 μm or more after cutting.

[0109] By performing the width trimming, even in a case where cracks or defects occur in the end portion of the cold-rolled steel sheet, the portion is cut off, whereby the steel sheet can be provided for a subsequent step, which is preferable in terms of cost and yield.

[Annealing Step]

[0110] In the annealing step, the cold-rolled steel sheet after the cold rolling step is performed or further after the width trimming step is performed if necessary, is heated to an annealing temperature of higher than $\text{Ac}3^\circ\text{C}$ and is held at this annealing temperature.

[0111] When the annealing temperature is $\text{Ac}3^\circ\text{C}$ or lower, the structure does not sufficiently undergo austenitic transform, and a desired microstructure primarily containing martensite cannot be obtained after the annealing step.

[0112] On the other hand, excessive high-temperature heating such that an annealing temperature of higher than 900°C leads to an increase in manufacturing cost. Therefore, the annealing temperature is preferably set to 900°C or lower.

[0113] A temperature ($^\circ\text{C}$) at the $\text{Ac}3$ point can be obtained by the following method.

$$\text{Ac}3 = 910 - (203 \times \text{C}^{1/2}) + 44.7 \times \text{Si} - 30 \times \text{Mn} + 700 \times \text{P} - 20 \times \text{Cu} - 15.2 \times \text{Ni} - 11 \times \text{Cr} + 31.5 \times \text{Mo} + 400 \times \text{Ti} + 104 \times \text{V} + 120 \times \text{Al}$$

[0114] Here, element symbols included in the formula mean amounts of the elements that are contained in the steel sheet in the unit of "mass%".

[0115] A holding time at the annealing temperature is preferably 40 to 135 seconds.

[0116] When the holding time is shorter than 40 seconds, there are cases where austenitizing does not sufficiently progress. In addition, when the holding time is longer than 135 seconds, productivity decreases.

[0117] The cold-rolled steel sheet after the holding is cooled to a cooling stop temperature so that an average cooling rate to 400°C is 10 $^\circ\text{C}/\text{sec}$ or faster and an average cooling rate from 400°C to a cooling stop temperature of 100°C or lower is 15 $^\circ\text{C}/\text{sec}$ or faster.

[0118] When the average cooling rate to 400°C is slower than 10 $^\circ\text{C}/\text{sec}$, there is a possibility that ferrite is generated in the microstructure. In addition, in a case where the average cooling rate from 400°C to the cooling stop temperature (100°C or lower) is slower than 15 $^\circ\text{C}/\text{sec}$ or the cooling stop temperature is higher than 100°C , there is a possibility that bainite is generated in the microstructure. In these cases, a desired microstructure cannot be obtained.

[0119] In the annealing step, a coating layer made of zinc, aluminum, or magnesium, or an alloy of one or more of these metals may be formed on the surface (one or both surfaces) of the cold-rolled steel sheet.

[0120] In the case of forming the coating layer, for example, in a case of hot-dip plating, in a range in which the average cooling rate to 400°C is 10 °C/sec or faster and the average cooling rate from 400°C to a cooling stop temperature of 100°C or lower is 15 °C/sec or faster, the steel sheet may be immersed in a plating bath during the cooling to form a hot-dip plating on the surface and held in a temperature range of 450°C to 470°C for 10 to 40 seconds.

[0121] In a case where an alloying treatment is applied to the hot-dip plating layer, it is preferable to heat the steel sheet on which the hot-dip galvanized layer is formed by immersing the steel sheet in the plating bath to a temperature range of 470°C to 550°C (alloying temperature), and hold the heated steel sheet in the temperature range for 10 to 40 seconds. When the alloying temperature is lower than 470°C, there is a concern that alloying may not proceed sufficiently. On the other hand, when the alloying temperature is higher than 550°C, alloying proceeds excessively, and an Fe concentration in the plating layer is higher than 15% due to the generation of a Γ phase, and there is a concern of deterioration of corrosion resistance. The alloying temperature is more preferably 480°C or higher. In addition, the alloying temperature is more preferably 540°C or lower.

[Heat Treatment Step]

[0122] By the cooling in the annealing step (cooling after holding), in the microstructure of the cold-rolled steel sheet, untransformed austenite is transformed into martensite. However, there are cases where a portion of austenite is not transformed and becomes retained austenite.

[0123] Such a cold-rolled steel sheet is subjected to a heat treatment by heating the cold-rolled steel sheet to a temperature range of 200°C to 350°C and holding the cold-rolled steel sheet in this temperature range.

[0124] By this heat treatment, a portion or the entirety of martensite becomes tempered martensite. In a case where a microstructure primarily containing tempered martensite is to be formed, the holding time is preferably set to 1 second or longer.

[0125] When a heating temperature is lower than 200°C, there are cases where martensite is not sufficiently tempered and satisfactory changes in microstructure and mechanical properties cannot be achieved. In a case where the heating temperature is higher than 350°C, a dislocation density in tempered martensite decreases, which may lead to a decrease in tensile strength.

[Skin Pass Rolling Step]

[0126] In the skin pass rolling step, the cold-rolled steel sheet after the heat treatment step is subjected to skin pass rolling at a rolling reduction of 0.1% or more.

[0127] As described above, the cold-rolled steel sheet after the heat treatment step has a difference in sheet thickness of 10 μm or more between the center portion in the width direction and the edge portion.

[0128] In a case where such a cold-rolled steel sheet is subjected to skin pass rolling, when the steel sheet is bitten into a rolling roll, the steel sheet is bitten so that a longitudinal direction of the steel sheet is not perpendicular but is at a predetermined angle with respect to an axial direction of the rolling roll due to the difference in sheet thickness. When the rolling is performed, any rolling reduction may be selected by settings a skin pass rolling mill. However, in a case where there is a difference in sheet thickness, the amount of strain introduced into the surface layer portion can be even higher than the amount of strain assumed to be introduced by the rolling reduction set in a case where the sheet thickness is uniform.

[0129] In the present embodiment, by performing the skin pass rolling on the cold-rolled steel sheet having a predetermined difference in sheet thickness to introduce strain into the surface layer portion, it is possible to increase the dislocation density of the surface layer portion and immobilize dislocations.

[0130] However, when the rolling reduction is less than 0.1%, a sufficient effect cannot be obtained. Therefore, the rolling reduction is set to 0.1% or more. An upper limit of the rolling reduction is not limited. However, when the upper limit thereof is more than 1.5%, the productivity significantly decreases. Therefore, the upper limit is preferably set to less than 1.5%.

[0131] In general, skin pass rolling with a rolling reduction of 0.1% or more is not performed on a steel sheet having a tensile strength of 1,310 MPa or more. However, in the present embodiment, skin pass rolling with a rolling reduction of 0.1% or more is performed based on the above-described new findings found by the present inventors.

[Examples]

[0132] Slabs (kinds of steel A to W) having the chemical composition shown in Tables 1-1 and 1-2 (unit: mass%, remainder: Fe and impurities) were manufactured by continuous casting.

[0133] Using these slabs, hot rolling was performed such that a finish rolling completion temperature reached $Ac3^{\circ}C$ or higher, and coiling was performed under the conditions shown in Table 2-1 by changing cooling conditions between a center portion and an edge portion, thereby obtaining hot-rolled steel sheets.

[0134] These hot-rolled steel sheets were cold-rolled under the conditions shown in Table 2-1 to obtain cold-rolled steel sheets having a difference in sheet thickness shown in Table 2-1.

[0135] These cold-rolled steel sheets were subjected to annealing, a heat treatment, and skin pass rolling under the conditions shown in Table 2-2.

[0136] In addition, hot-dip galvanizing was performed on some of the cold-rolled steel sheets during the annealing. By changing a holding temperature after immersion in a plating bath, some of plating layers were alloyed. A holding time was set to 10 to 40 seconds. In Table 3-1, GI indicates that a hot-dip galvanized layer is formed, and GA indicates that a hot-dip galvannealed layer is formed.

[0137] From the obtained cold-rolled steel sheets, a microstructure of a $t/4$ portion was observed by the above-described method, and volume percentages of martensite, tempered martensite, bainite, retained austenite, ferrite, and pearlite were measured.

[0138] Table 3-1 shows measurement results of the volume percentages of martensite, tempered martensite, bainite, and retained austenite. Although not shown in the table, in Nos. 38 and 39, ferrite was generated in addition to martensite, tempered martensite, bainite, and retained austenite.

[0139] In addition, from the obtained cold-rolled steel sheets, dislocation densities and hardnesses of a surface layer portion and a $t/4$ portion were measured by the above-described method.

[0140] Results are shown in Table 3-2. However, regarding the notation of the dislocation density, " $5.0E + 15$ " in the table means 5.0×10^{15} , and $YE + X$ also means $Y \times 10^X$ in the same manner.

[0141] In addition, a tensile strength of the obtained cold-rolled steel sheet was obtained. The tensile strength was obtained by the following method.

[0142] The tensile strength (TS) was measured by collecting a JIS No. 5 test piece from an orientation in which a longitudinal direction of the test piece was parallel to an orthogonal-to-rolling direction of the steel sheet and conducting a tensile test in accordance with JIS Z 2241 (2011).

[0143] Results are shown in Table 3-2.

[0144] In addition, in order to evaluate a decrease in flow stress, a tensile test after prestrain was conducted in the following manner.

[0145] A change in flow stress was evaluated by collecting a JIS No. 5 test piece from an orientation in which a longitudinal direction of the test piece was parallel to the orthogonal-to-rolling direction of the steel sheet, and comparing a stress in a case where a prestrain of 0.1% was applied in accordance with JIS Z 2241 (2011), the steel sheet was left for one day after removing the prestrain, and the test piece was pulled again, to a stress when a prestrain of 0.1% was applied. A case where the flow stress when the strain was applied again had increased or was the same or a case where a decrease was smaller than 40 MPa was evaluated as A (excellent), a case where a decrease was 40 MPa or more and less than 80 MPa was evaluated as B (good), and a case where a decrease was 80 MPa or more was evaluated as C (does not meet the target).

[0146] Results are shown in Table 3-2.

mass%, remainder Fe and impurities

Kind of steel	mass%, remainder Fe and impurities																
	C	Si	Mn	P	S	Al	N	O	Ni	Mo	Cr	B	As	Co	Ti	Nb	V
A	0.238	1.17	2.60	0.0154	0.0015	0.030	0.0013	0.006									
B	0.277	0.80	1.30	0.0014	0.0009	0.057	0.0009	0.001									
C	0.419	1.94	1.10	0.0043	0.0027	0.066	0.0068	0.003									
D	0.156	0.62	1.80	0.0017	0.0021	0.044	0.0158	0.004									
B	0.216	1.75	0.60	0.0020	0.0018	0.050	0.0011	0.002									
F	0.301	1.21	2.00	0.0020	0.0062	0.022	0.0028	0.001									
G	0.162	1.38	2.30	0.0009	0.0009	0.019	0.0016	0.001									
H	0.206	1.58	1.90	0.0013	0.0029	0.004	0.0021	0.002									
I	0.183	0.96	0.90	0.0016	0.0015	0.081	0.0023	0.015									
J	0.466	0.28	1.70	0.0070	0.0036	0.072	0.0036	0.001									
K	0.165	0.82	0.70	0.0028	0.0120	0.089	0.0125	0.001				0.006			0.102		
L	0.260	0.54	1.60	0.0013	0.0015	0.036	0.0022	0.003		0.694	0.322			0.148			
M	0.308	0.13	1.40	0.0017	0.0010	0.013	0.0015	0.002	0.318		0.727					0.033	
N	0.339	0.32	2.50	0.0128	0.0153	0.076	0.0010	0.012							0.226	0.111	0.112
O	0.192	1.65	2.70	0.0026	0.0021	0.094	0.0022	0.001	0.715					0.348			
P	0.456	0.52	0.50	0.0067	0.0013	0.024	0.0154	0.002					0.030				
Q	0.265	1.78	0.80	0.0126	0.0017	0.074	0.0020	0.002		0.463	1.385						
R	0.172	1.41	1.30	0.0152	0.0045	0.048	0.0035	0.002				0.002			0.062		
S	0.276	0.57	3.00	0.0023	0.0073	0.089	0.0018	0.016					0.010		0.181	0.445	0.061
T	0.234	0.78	2.60	0.0019	0.0018	0.017	0.0018	0.003					0.012				
U	0.501	0.50	1.20	0.0018	0.0126	0.003	0.0024	0.002		0.363	0.840						
V	0.120	0.20	0.65	0.0044	0.0022	0.044	0.0011	0.012					0.034		0.052	0.067	0.020
W	0.152	0.38	0.30	0.0019	0.0018	0.062	0.0020	0.001	0.020			0.004		0.372	0.043		

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[Table 1-2]

Kind of steel	mass%, remainder Fe and impurities											Ac3 [°C]
	Cu	W	Ta	Ca	Mg	La	Ce	Y	Zr	Sb	Sn	
A												796
B												801
C												836
D												807
E												877
F												794
G												822
H												833
I												840
J												738
K												887
L												802
M	0.437											741
N												842
O												805
P				0.038	0.020			0.037		0.011		788
Q		0.081	0.082			0.029	0.049		0.014		0.022	869
R								0.013	0.037		0.038	886
S						0.044			0.033	0.038		819
T			0.087		0.035	0.041	0.031					770
U	0.114											754
V				0.025	0.016			0.029		0.018		855
W		0.064	0.037			0.019	0.024		0.029		0.007	857

[Table 2-1]

No.	Kind of steel	Classification	Hot rolling, coiling		Cold rolling	
			Coiling temperature of center portion in width direction [°C]	Coiling temperature at position 20 mm away from end portion in width direction [°C]	Rolling reduction [%]	Difference in sheet thickness after cold rolling (sheet thickness of center portion in width direction - sheet thickness of edge portion) [μm]
1	A	Invention Example	625	475	80	31
2	B	Invention Example	636	523	48	28
3	C	Invention Example	677	591	45	16

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(continued)

No.	Kind of steel	Classification	Hot rolling, coiling		Cold rolling	
			Coiling temperature of center portion in width direction [°C]	Coiling temperature at position 20 mm away from end portion in width direction [°C]	Rolling reduction [%]	Difference in sheet thickness after cold rolling (sheet thickness of center portion in width direction - sheet thickness of edge portion) [μm]
4	D	Invention Example	695	551	62	33
5	E	Invention Example	619	562	32	14
6	F	Invention Example	653	481	66	51
7	G	Invention Example	682	507	73	45
8	H	Invention Example	671	537	64	29
9	I	Invention Example	609	443	39	35
10	J	Invention Example	690	561	88	26
11	K	Invention Example	604	422	36	37
12	L	Invention Example	632	482	56	29
13	M	Invention Example	645	512	51	31
14	N	Invention Example	654	493	77	47
15	O	Invention Example	662	547	83	25
16	P	Invention Example	622	458	67	34
17	Q	Invention Example	643	501	62	28
18	R	Invention Example	649	466	77	34
19	S	Invention Example	688	481	33	52
20	T	Invention Example	616	580	45	11
21	A	Invention Example	631	446	41	56
22	B	Invention Example	639	549	81	17

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(continued)

No.	Kind of steel	Classification	Hot rolling, coiling		Cold rolling	
			Coiling temperature of center portion in width direction [°C]	Coiling temperature at position 20 mm away from end portion in width direction [°C]	Rolling reduction [%]	Difference in sheet thickness after cold rolling (sheet thickness of center portion in width direction - sheet thickness of edge portion) [μm]
23	C	Invention Example	676	526	49	28
24	D	Invention Example	604	495	51	19
25	E	Invention Example	662	492	83	41
26	F	Invention Example	657	439	37	34
27	G	Invention Example	608	552	55	15
28	H	Invention Example	681	513	63	35
29	I	Invention Example	699	571	88	26
30	J	Invention Example	671	532	71	34
31	U	Comparative Example	625	475	80	32
32	V	Comparative Example	636	532	48	25
33	W	Comparative Example	677	591	45	15
34	K	Comparative Example	597	496	65	8
35	L	Comparative Example	703	603	49	15
36	M	Comparative Example	622	609	84	5
37	N	Comparative Example	683	581	28	9
38	O	Comparative Example	658	562	53	18
39	P	Comparative Example	648	549	62	20
40	Q	Comparative Example	683	571	58	21
41	E	Comparative Example	630	518	43	19

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(continued)

No.	Kind of steel	Classification	Hot rolling, coiling		Cold rolling	
			Coiling temperature of center portion in width direction [°C]	Coiling temperature at position 20 mm away from end portion in width direction [°C]	Rolling reduction [%]	Difference in sheet thickness after cold rolling (sheet thickness of center portion in width direction - sheet thickness of edge portion) [μm]
42	T	Comparative Example	688	562	76	24
43	A	Comparative Example	<u>582</u>	530	62	3
44	N	Comparative Example	597	503	49	9
45	B	Comparative Example	664	586	52	15

[Table 2-2]

No.	Annealing						Heat treatment	Skin pass rolling	Note
	Annealing temperature [°C]	Average cooling rate to 400°C [°C/sec]	Average cooling rate from 400°C to cooling stop temperature [°C/sec]	Cooling stop temperature [°C/sec]	Presence or absence of plating	Holding temperature after immersion in plating bath [°C]	Temperature [°C]	Rolling reduction [%]	Ac3 point [°C]
1	813	18	30	65	Present	457	244	0.2	796
2	830	11	43	58	Present	512	213	0.5	801
3	878	39	48	52	Absent	-	325	0.1	836
4	812	33	37	61	Absent	-	344	0.9	807
5	881	27	40	59	Present	465	223	1.2	877
6	828	46	26	66	Absent	-	331	0.3	794
7	831	14	24	69	Present	483	264	0.6	822
8	840	41	16	77	Absent	-	259	0.9	833
9	846	29	55	48	Present	491	287	0.1	840
10	741	44	51	51	Absent	-	342	0.4	738
11	891	49	59	48	Absent	-	335	2.5	887
12	804	21	33	68	Present	472	278	1.4	802
13	762	22	21	72	Present	531	207	1.2	741
14	851	52	53	49	Absent	-	232	0.3	842
15	810	36	62	41	Absent	-	293	0.8	805
16	797	20	63	46	Present	459	325	1.2	788
17	889	34	59	50	Absent	-	239	0.6	869
18	891	43	34	67	Absent	-	342	0.3	886

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(continued)

No.	Annealing						Heat treatment	Skin pass rolling	Note
	Annealing temperature [°C]	Average cooling rate to 400°C [°C/sec]	Average cooling rate from 400°C to cooling stop temperature [°C/sec]	Cooling stop temperature [°C/sec]	Presence or absence of plating	Holding temperature after immersion in plating bath [°C]	Temperature [°C]	Rolling reduction [%]	Ac3 point [°C]
19	832	48	40	62	Absent	-	307	2.1	819
20	796	12	45	48	Present	499	214	1.8	770
21	811	15	52	51	Present	503	293	1.9	796
22	805	38	48	51	Absent	-	278	0.2	801
23	863	17	37	59	Present	523	315	0.9	836
24	814	40	47	51	Absent	-	321	1.3	807
25	881	26	24	72	Present	481	223	0.2	877
26	795	51	16	79	Absent	-	343	1.3	794
27	842	32	55	48	Absent	-	332	1.9	822
28	871	53	31	65	Absent	-	258	0.9	833
29	847	29	28	67	Present	511	263	0.2	840
30	777	23	20	66	Present	467	321	0.1	738
31	799	18	30	62	Present	507	346	0.4	754
32	863	11	43	50	Present	467	341	1.4	855
33	891	39	48	49	Absent	-	347	1.9	857
34	888	36	35	73	Absent	-	333	0.8	887
35	805	46	47	47	Absent	-	327	1.1	802
36	745	34	59	42	Absent	-	215	0.2	741
37	867	31	43	56	Absent	-	310	1.1	842
38	751	51	27	64	Absent	-	277	0.8	788
39	871	9	50	61	Present	488	349	0.7	869
40	886	20	14	81	Present	460	261	2.1	886
41	890	38	42	55	Absent	-	362	0.4	877
42	811	11	55	40	Present	523	314	0.0	796
43	826	48	28	61	Absent	-	266	0.0	796
44	853	46	47	52	Absent	-	327	0.3	842
45	881	53	41	49	Absent	-	<u>482</u>	0.0	801

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[Table 3-1]

No.	Kind of steel	Classification	Kind of plating	t/4 portion microstructure				
				Martensite [volume%]	Tempered martensite [volume%]	Bainite [volume%]	Sum of martensite and tempered martensite [volume%]	Retained γ [volume%]
1	A	Invention Example	GI	1.8	90.9	5.4	92.7	1.9
2	B	Invention Example	GA	2.3	89.1	6.9	91.4	1.7
3	C	Invention Example	-	1.2	93.8	2.1	95.0	2.9
4	D	Invention Example	-	2.6	91.2	2.7	93.8	3.5
5	E	Invention Example	GI	4.1	88.4	4.8	92.5	2.7
6	F	Invention Example	-	1.6	93.0	3.6	94.6	1.8
7	G	Invention Example	GA	2.2	92.0	5.2	94.2	0.6
8	H	Invention Example	-	3.1	90.1	3.9	93.2	2.9
9	I	Invention Example	GA	2.8	90.3	5.3	93.1	1.6
10	I	Invention Example	-	0.4	93.1	3.6	93.5	2.9
11	K	Invention Example	-	1.3	92.7	4.1	94.0	1.9
12	L	Invention Example	GA	3.5	86.7	4.9	90.2	4.9
13	M	Invention Example	GA	2.9	87.2	7.0	90.1	2.9
14	N	Invention Example	-	0.4	94.6	3.4	95.0	1.6
15	O	Invention Example	-	0.9	93.1	4.2	94.0	1.8
16	P	Invention Example	GI	2.7	91.2	4.8	93.9	1.3
17	Q	Invention Example	-	1.1	95.1	3.2	96.2	0.6
18	R	Invention Example	-	0.4	94.6	4.1	95.0	0.9
19	S	Invention Example	-	2.3	91.5	2.8	93.8	3.4
20	T	Invention Example	GA	3.3	88.0	5.0	91.3	3.7

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(continued)

No.	Kind of steel	Classification	Kind of plating	t/4 portion microstructure				
				Martensite [volume%]	Tempered martensite [volume%]	Bainite [volume%]	Sum of martensite and tempered martensite [volume%]	Retained γ [volume%]
21	A	Invention Example	GA	2.9	88.0	5.3	90.9	3.8
22	B	Invention Example	-	1.4	92.9	2.4	94.3	3.3
23	C	Invention Example	GA	2.1	88.6	7.2	90.7	2.1
24	D	Invention Example	-	0.6	95.1	2.6	95.7	1.7
25	E	Invention Example	GA	2.8	89.6	5.7	92.4	1.9
26	F	Invention Example	-	1.5	94.1	2.9	95.6	1.5
27	G	Invention Example	-	1.3	94.8	3.1	96.1	0.8
28	H	Invention Example	-	0.8	95.4	2.8	96.2	1.0
29	I	Invention Example	GA	2.7	87.6	6.8	90.3	2.9
30	I	Invention Example	GI	2.1	91.5	4.6	93.6	1.8
31	<u>U</u>	Comparative Example	GA	3.2	88.4	5.6	91.6	2.8
32	<u>V</u>	Comparative Example	GI	1.9	89.7	4.5	91.6	3.9
33	<u>W</u>	Comparative Example	-	0.4	94.6	3.2	95.0	1.8
34	K	Comparative Example	-	1.4	94.3	2.4	95.7	1.9
35	L	Comparative Example	-	0.8	94.1	2.9	94.9	2.2
36	M	Comparative Example	-	1.2	93.6	3.4	94.8	1.8
37	N	Comparative Example	-	1.9	92.2	3.1	94.1	2.8
38	O	Comparative Example	-	0.2	86.2	2.8	<u>86.4</u>	3.2
39	P	Comparative Example	GA	2.3	82.1	53	84.4	1.3

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(continued)

No.	Kind of steel	Classification	Kind of plating	t/4 portion microstructure				
				Martensite [volume%]	Tempered martensite [volume%]	Bainite [volume%]	Sum of martensite and tempered martensite [volume%]	Retained γ [volume%]
40	Q	Comparative Example	GI	2.1	89.8	5.2	91.9	2.9
41	E	Comparative Example	-	0.6	94.8	2.1	95.4	2.5
42	T	Comparative Example	GA	1.8	91.5	4.3	93.3	2.4
43	A	Comparative Example	-	0.8	95.9	2.9	96.7	0.4
44	N	Comparative Example	-	1.2	95.1	2.1	96.3	1.6
45	B	Comparative Example	-	0.4	93.4	3.4	93.8	2.8

[Table 3-2]

No.	Dislocation density			Hardness			Tensile strength [MPa]	Tensile test after prestrain
	Surface layer portion [m ⁻²]	t/4 portion [m ⁻²]	Ratio of dislocation density of surface layer portion to dislocation density of t/4 portion [-]	Surface layer portion [Hv]	t/4 portion [Hv]	Ratio of hardness of surface layer portion to hardness of t/4 portion [-]		
1	5.0E+15	6.1E+15	0.83	453	498	0.91	1876	B
2	5.7E+15	6.4E+15	0.89	465	505	0.92	1906	A
3	4.3E+15	5.3E+15	0.81	433	471	0.92	1770	B
4	4.7E+15	5.1E+15	0.92	398	428	0.93	1600	A
5	6.0E+15	6.3E+15	0.95	395	429	0.92	1603	A
6	4.5E+15	5.2E+15	0.87	473	519	0.91	1962	B
7	5.3E+15	5.9E+15	0.91	449	477	0.94	1797	A
8	4.9E+15	5.9E+15	0.83	453	498	0.91	1876	B
9	4.6E+15	5.6E+15	0.81	422	449	0.94	1682	B
10	4.4E+15	5.1E+15	0.86	475	516	0.92	1951	A
11	5.0E+15	5.2E+15	0.97	387	416	0.93	1551	A
12	5.3E+15	5.7E+15	0.92	442	480	0.92	1808	A
13	5.9E+15	6.4E+15	0.92	466	512	0.91	1933	A
14	5.1E+15	6.2E+15	0.82	488	525	0.93	1984	B
15	5.0E+15	5.6E+15	0.90	459	504	0.91	1903	A

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(continued)

No.	Dislocation density			Hardness			Tensile strength [MPa]	Tensile test after prestrain
	Surface layer portion [m ⁻²]	t/4 portion [m ⁻²]	Ratio of dislocation density of surface layer portion to dislocation density of t/4 portion [-]	Surface layer portion [Hv]	t/4 portion [Hv]	Ratio of hardness of surface layer portion to hardness of t/4 portion [-]		
16	4.8E+15	5.3E+15	0.92	471	512	0.92	1935	A
17	5.4E+15	6.1E+15	0.89	426	454	0.94	1702	A
18	4.3E+15	5.1E+15	0.85	408	449	0.91	1683	B
19	5.3E+15	5.4E+15	0.98	455	506	0.90	1908	A
20	6.0E+15	6.4E+15	0.94	445	483	0.92	1820	A
21	5.3E+15	5.6E+15	0.95	458	504	0.91	1901	A
22	4.7E+15	5.7E+15	0.82	450	484	0.93	1821	B
23	4.7E+15	5.4E+15	0.88	438	476	0.92	1790	A
24	5.0E+15	5.3E+15	0.95	410	451	0.91	1690	A
25	5.1E+15	6.3E+15	0.82	395	429	0.92	1603	B
26	4.2E+15	5.1E+15	0.83	477	508	0.94	1917	A
27	5.0E+15	5.2E+15	0.96	424	466	0.91	1752	A
28	5.2E+15	5.9E+15	0.88	457	497	0.92	1875	A
29	4.8E+15	5.9E+15	0.82	410	441	0.93	1652	B
30	4.3E+15	5.3E+15	0.81	486	528	0.92	1996	B
31	4.1E+15	5.0E+15	0.82	542	596	0.91	2268	C
32	4.7E+15	5.1E+15	0.93	311	345	0.90	<u>1271</u>	A
33	4.7E+15	5.0E+15	0.93	322	350	0.92	<u>1292</u>	A
34	3.7E+15	5.2E+15	<u>0.72</u>	339	418	<u>0.81</u>	1561	C
35	3.9E+15	5.2E+15	<u>0.75</u>	409	493	<u>0.83</u>	1859	C
36	4.6E+15	6.4E+15	<u>0.73</u>	400	507	0.79	1913	C
37	4.2E+15	5.4E+15	<u>0.78</u>	441	507	<u>0.87</u>	1914	C
38	4.4E+15	5.7E+15	<u>0.76</u>	424	505	<u>0.84</u>	1906	C
39	3.7E+15	5.0E+15	0.73	392	484	<u>0.81</u>	1822	C
40	4.5E+15	5.9E+15	<u>0.76</u>	370	445	<u>0.83</u>	1669	C
41	3.8E+15	4.5E+15	0.85	315	350	0.90	<u>1292</u>	B
42	3.9E+15	5.4E+15	<u>0.72</u>	392	496	<u>0.79</u>	1871	C
43	5.4E+15	5.8E+15	0.92	415	500	<u>0.83</u>	1887	C
44	4.1E+15	5.2E+15	<u>0.79</u>	461	501	0.92	1890	C
45	1.5E+15	1.8E+15	0.81	280	329	<u>0.85</u>	<u>1206</u>	C

[0147] As can be seen from Tables 1-1 to 3-2, in Invention Example Nos. 1 to 30, a tensile strength of 1,310 MPa or more was obtained, and a decrease in flow stress was also suppressed to less than 80 MPa.

[0148] On the other hand, in Comparative Example Nos. 31 to 45, a tensile strength of 1,310 MPa or more could not be obtained, or a decrease in flow stress of 80 MPa or more was observed.

Claims

1. A cold-rolled steel sheet comprising, as a chemical composition, by mass%:

C: 0.150% to 0.500%;

Si: 0.01% to 2.00%;

Mn: 0.50% to 3.00%;

P: 0.0200% or less;

S: 0.0200% or less;

Al: 0.100% or less;

N: 0.0200% or less;

O: 0.020% or less;

Ni: 0% to 1.000%;

Mo: 0% to 1.000%;

Cr: 0% to 2.000%;

B: 0% to 0.010%;

As: 0% to 0.050%;

Co: 0% to 0.500%;

Ti: 0% to 0.500%;

Nb: 0% to 0.500%;

V: 0% to 0.500%;

Cu: 0% to 0.500%;

W: 0% to 0.100%;

Ta: 0% to 0.100%;

Ca: 0% to 0.050%;

Mg: 0% to 0.050%;

La: 0% to 0.050%;

Ce: 0% to 0.050%;

Y: 0% to 0.050%;

Zr: 0% to 0.050%;

Sb: 0% to 0.050%;

Sn: 0% to 0.050%; and

a remainder: Fe and impurities,

wherein, in a case where a range of 1/8 to 3/8 of a sheet thickness from a surface in a sheet thickness direction is defined as a t/4 portion and a range of 20 μ m from the surface in the sheet thickness direction is defined as a surface layer portion,

a microstructure at the t/4 portion includes, by volume percentage, 0% or more and 10.0% or less of retained austenite and 90.0% or more and 100% or less of one or two of martensite and tempered martensite,

a ratio of a dislocation density of the surface layer portion to a dislocation density of the t/4 portion is 0.80 or more,

a ratio of a hardness of the surface layer portion to a hardness of the t/4 portion is 0.90 or more, and

a tensile strength of the cold-rolled steel sheet is 1,310 MPa or more.

2. The cold-rolled steel sheet according to claim 1,

wherein a coating layer made of zinc, aluminum, or magnesium, or an alloy of one or more of these metals is provided on the surface.

3. A manufacturing method of a cold-rolled steel sheet, comprising:

a hot rolling process of performing hot rolling on a slab having the chemical composition according to claim 1 to obtain a hot-rolled steel sheet, and coiling the hot-rolled steel sheet in a state in which a temperature of a center portion in a width direction is higher than 600°C and 700°C or lower and a temperature of an edge portion at a position 20 mm away from an end portion in the width direction is 600°C or lower;

a cold rolling process of pickling the hot-rolled steel sheet after the hot rolling process and performing cold rolling on the hot-rolled steel sheet at a rolling reduction of 30% to 90% to obtain a cold-rolled steel sheet;

an annealing process of heating the cold-rolled steel sheet to an annealing temperature of higher than Ac3°C, holding the cold-rolled steel sheet at the annealing temperature, and cooling the cold-rolled steel sheet after the holding to a cooling stop temperature so that an average cooling rate to 400°C is 10 °C/sec or faster and an average cooling rate from 400°C to the cooling stop temperature of 100°C or lower is 15 °C/sec or faster;

a heat treatment process of heating the cold-rolled steel sheet after the annealing process to a temperature range of 200°C to 350°C and holding the cold-rolled steel sheet in the temperature range; and
a skin pass rolling process of performing skin pass rolling on the cold-rolled steel sheet after the heat treatment process at a rolling reduction of 0.1% or more,

wherein a difference between a sheet thickness of the center portion in the width direction and a sheet thickness of the edge portion of the cold-rolled steel sheet after the cold rolling process is 10 μm or more.

4. The manufacturing method of a cold-rolled steel sheet according to claim 3,
wherein, in the annealing process, a coating layer made of zinc, aluminum, or magnesium, or an alloy of one or more of these metals is formed on front and rear surfaces of the cold-rolled steel sheet.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/027703

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/00(2006.01)i; C21D 9/46(2006.01)i; C22C 38/60(2006.01)i

FI: C22C38/00 301U; C22C38/00 301T; C22C38/60; C21D9/46 F; C21D9/46 H

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)

C22C38/00-38/60; C21D9/46-9/48

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

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2022
 Registered utility model specifications of Japan 1996-2022
 Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2020/026838 A1 (JFE STEEL CORP.) 06 February 2020 (2020-02-06)	1-4
A	WO 2021/085336 A1 (JFE STEEL CORP.) 06 May 2021 (2021-05-06)	1-4
A	WO 2018/026013 A1 (NIPPON STEEL & SUMITOMO METAL CORP.) 08 February 2018 (2018-02-08)	1-4
A	JP 2016-60955 A (KOBE STEEL, LTD.) 25 April 2016 (2016-04-25)	3-4

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

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Date of the actual completion of the international search

09 September 2022

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20 September 2022

Name and mailing address of the ISA/JP

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Authorized officer

Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/027703

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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