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(54) **COLD-ROLLED STEEL SHEET, METHOD FOR MANUFACTURING SAME, AND WELDED JOINT**

(57) This cold-rolled steel sheet has a predetermined chemical composition, in which a metallographic structure at a position of 1/4 to 3/4 of a sheet thickness in a sheet thickness direction from a surface contains, 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, in the metallographic structure at the position, a P content at prior γ grain boundaries is 10.0 mass% or less, and a Mn content at the prior γ grain boundaries is 10.0 mass% or less, and a tensile strength is 1,310 MPa or more.

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Description

[Technical Field of the Invention]

5 **[0001]** The present invention relates to a cold-rolled steel sheet, a method for manufacturing the same, and a welded joint.

[0002] Priority is claimed on Japanese Patent Application No. 2021-168157, filed October 13, 2021, the content of which is incorporated herein by reference.

10 [Related Art]

[0003] Nowadays, 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.

20 **[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 /mm² 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.

35 **[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 includes iron and unavoidable impurities, 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 1/4 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.

40 [Prior Art Document]

[Patent Document]

45 **[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

50 [Disclosure of the Invention]

[Problems to be Solved by the Invention]

55 **[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 such a high strength steel sheet, the amount of an alloying element such as Mn is generally large, and segregation of the alloying element such as Mn is observed in the steel sheet. In addition, it is known that P, which is contained as an impurity together with Mn, segregates in the steel sheet. The segregation of Mn and P occurs

when elements are distributed between a solid phase and a liquid phase during dendrite growth during solidification from molten steel. Since these elements diffuse slowly in steel, the segregation during solidification cannot be eliminated by only heating during hot rolling, annealing, or the like after solidification.

[0010] As a result of studies conducted by the present inventors, it was found that in a case where a steel sheet having such segregation is welded, there can be a decrease in joint strength in a heat-affected zone of a welded part due to segregation of the steel sheet. However, in Patent Documents 1 to 3, joint strength after welding is not considered.

[0011] Therefore, an object of the present invention is to provide a steel sheet in which a sufficiently high joint strength can be obtained after welding on the premise of an ultrahigh-strength steel sheet having a tensile strength of 1,310 MPa or more. Another object of the present invention is to provide a welded joint using this steel sheet.

[Means for Solving the Problem]

[0012] The present inventors investigated the reason why the joint strength decreases due to the segregation of Mn and P. As a result, it was found that a difference in hardness of martensite in a welded heat-affected zone, caused by a difference in Mn content (difference in concentration), and co-segregation of Mn and P cause cracking to occur more easily. In addition, it was also found that Mn and P tend to segregate at prior γ (austenite) grain boundaries.

[0013] Therefore, the present inventors examined methods for suppressing segregation of Mn and P to prior γ grain boundaries.

[0014] As a result, it was found that the segregation of Mn and P to prior γ grain boundaries can be suppressed by performing a breakdown (BD) and a high-temperature heat treatment (SP treatment) on a cast slab prior to hot rolling and further performing a large reduction during the hot rolling.

[0015] In addition, it was found that in a case where a steel sheet in which such segregation is suppressed is used, a decrease in joint characteristics after welding can be suppressed.

[0016] 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: 0.200% or more and 0.450% or less; Si: 0.01% or more and 2.50% or less; Mn: 0.6% or more and 3.5% or less; Al: 0.001% or more and 0.100% or less; Ti: 0.001% or more and 0.100% or less; N: 0.0100% or less; P: 0.0400% or less; S: 0.0100% or less; O: 0.0060% or less; B: 0% or more and 0.0100% or less; Mo: 0% or more and 0.500% or less; Nb: 0% or more and 0.200% or less; Cr: 0% or more and 2.00% or less; V: 0% or more and 0.500% or less; Co: 0% or more and 0.500% or less; Ni: 0% or more and 1.000% or less; Cu: 0% or more and 1.000% or less; W: 0% or more and 0.100% or less; Ta: 0% or more and 0.100% or less; Sn: 0% or more and 0.050% or less; Sb: 0% or more and 0.050% or less; As: 0% or more and 0.050% or less; Mg: 0% or more and 0.050% or less; Ca: 0% or more and 0.040% or less; Y: 0% or more and 0.050% or less; Zr: 0% or more and 0.050% or less; La: 0% or more and 0.050% or less; Ce: 0% or more and 0.050% or less; and a remainder comprising Fe and impurities, in which a metallographic structure at a position of 1/4 to 3/4 of a sheet thickness in a sheet thickness direction from a surface contains, 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, in the metallographic structure at the position, a P content at prior γ grain boundaries is 10.0 mass% or less, and a Mn content at the prior γ grain boundaries is 10.0 mass% or less, and a tensile strength is 1,310 MPa or more.

[2] A method for manufacturing a cold-rolled steel sheet according to another aspect of the present invention, includes: a continuous casting process of obtaining a slab having the chemical composition according to [1] by continuous casting; a breakdown process of reducing a thickness of the slab by performing a reduction at a reduction ratio of 30% to 60% in a temperature range of 850°C to 1,000°C; a high-temperature heat treatment process of heating the slab after the breakdown process to 1,000°C to 1,300°C, holding the slab for 5 to 20 hours, and cooling the slab; a hot rolling process of performing hot rolling on the slab after the high-temperature heat treatment process to obtain a hot-rolled steel sheet; a coiling process of coiling the hot-rolled steel sheet in a temperature range of 400°C to 650°C; a cold rolling process of pickling the hot-rolled steel sheet after the coiling process and performing cold rolling on the hot-rolled steel sheet at a reduction ratio of 20% to 80% 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 at an average temperature rising rate of 2 °C/sec or faster, holding the cold-rolled steel sheet at the annealing temperature for 60 to 300 seconds, and cooling the cold-rolled steel sheet to 250°C or lower at an average cooling rate of 10 °C/sec or faster; and a holding process of holding the cold-rolled steel sheet after the annealing process at 150°C to 400°C for 500 seconds or shorter, in which, in the hot rolling process, in a case where finish rolling is performed using a rolling mill having four or more stands, an initial stand is referred to as a first stand, and a last stand is referred to as an nth stand, a sheet thickness reduction ratio in each stand from a (n-3)th stand to the nth stand is set to 30% or more, and a rolling temperature in the nth stand is set to 900°C or lower.

[3] In the method for manufacturing a cold-rolled steel sheet according to [2], in the annealing process, a coating

layer containing zinc, aluminum, magnesium, or an alloy of these metals may be formed on front and rear surfaces of the steel sheet.

[4] A welded joint according to another aspect of the present invention is a welded joint obtained by joining a plurality of steel sheets together, in which at least one of the steel sheets is the cold-rolled steel sheet according to [1].

[Effects of the Invention]

[0017] According to the above aspects of the present invention, it is possible to provide a steel sheet which is an ultrahigh-strength steel sheet having a tensile strength of 1,310 MPa or more and can achieve sufficiently high joint strength after welding, and a welded joint.

[Brief Description of the Drawings]

[0018] FIG. 1 is a diagram showing a shape of a test piece for an Auger test.

[Embodiments of the Invention]

[0019] A cold-rolled steel sheet according to an embodiment of the present invention (a cold-rolled steel sheet according to the present embodiment), a method of manufacturing the same, and a welded joint obtained using the cold-rolled steel sheet according to the present embodiment will be described.

[Cold-Rolled Steel Sheet]

[0020] The cold-rolled steel sheet according to the present embodiment has a predetermined chemical composition, in which a metallographic structure at a position of 1/4 to 3/4 of a sheet thickness in a sheet thickness direction from a surface contains, 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, in the metallographic structure at the position, a P content at prior γ grain boundaries is 10.0 mass% or less, and a Mn content at the prior γ grain boundaries is 10.0 mass% or less, and a tensile strength of the cold-rolled steel sheet is 1,310 MPa or more.

<Chemical Composition>

[0021] First, the chemical composition will be described. In the present embodiment, % of an amount of each element means mass%.

C: 0.200% or More and 0.450% or Less

[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 and joint strength after welding. In order to obtain a tensile strength of 1,310 MPa or more, a C content is set to 0.200% or more. The C content is preferably 0.210% or more, and more preferably 0.220% or more.

[0023] On the other hand, when the C content is more than 0.450%, weldability deteriorates and formability deteriorates. Therefore, the C content is set to 0.450% or less. The C content is preferably 0.350% or less, and more preferably 0.300% or less.

Si: 0.01% or More and 2.50% or Less

[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 2.50% or less. The Si content is preferably 2.00% or less, and more preferably 1.80% or less.

Mn: 0.6% or More and 3.5% or Less

[0026] Mn is an element that increases hardenability of steel by segregating at prior γ grain boundaries and is an element that promotes the generation of martensite. When a Mn content is less than 0.6%, it becomes difficult to obtain a target microstructure. Therefore, the Mn content is set to 0.6% or more. The Mn content is preferably 1.0% or more.

[0027] On the other hand, when the Mn content is excessive, there is a concern that platability, workability, and weldability decrease. Particularly, the decrease in the weldability is caused by Mn segregating at prior γ grain boundaries. Therefore, the Mn content is set to 3.5% or less. The Mn content is preferably 3.0% or less.

5 Al: 0.001% or More and 0.100% or Less

[0028] Al is an element having an action of deoxidizing molten steel. Therefore, an Al content is 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.

10 **[0029]** On the other hand, when the Al content is too high, not only are surface defects caused by alumina 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.

15 Ti: 0.001% or More and 0.100% or Less

[0030] Ti is an element that is bonded to N to form TiN and contributes to the refinement of γ . The P content at γ grain boundaries can be suppressed by the refinement of γ . In order to obtain this effect, a Ti content is set to 0.001% or more. The Ti content is preferably 0.005% or more.

20 **[0031]** On the other hand, when the Ti content is excessive, 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 is set to 0.100% or less.

25 N: 0.0001% or More and 0.0100% or Less

[0032] N is an element that is bonded to Ti to form TiN. In order to form TiN, a N content is set to 0.0001% or more.

[0033] On the other hand, when the N content is high, coarse precipitates are generated and the formability deteriorates. Therefore, the N content is set to 0.0100% or less. The N content is preferably 0.0080% or less, and more preferably 0.0060% or less.

P: 0.0400% or Less

35 **[0034]** P is an element contained in steel as an impurity and is an element that segregates at grain boundaries and embrittles steel. Therefore, the 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 0.0400% or less. The P content is preferably 0.0200% or less, and more preferably 0.0150% or less.

[0035] From the viewpoint of a refining cost or the like, the P content may be set to 0.0001% or more.

40 S: 0.0100% or Less

[0036] 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 0.0100% or less. The S content is preferably 0.0050% or less, more preferably 0.0040% or less, and even more preferably 0.0030% or less.

[0037] From the viewpoint of a refining cost or the like, the S content may be set to 0.0001% or more.

O: 0.0060% or Less

50 **[0038]** O is an element that is contained as an impurity. When an O content is more than 0.0060%, coarse oxides are formed in steel, and the formability decreases. Therefore, the O content is set to 0.0060% or less. The O content is preferably 0.0050% or less, and more preferably 0.0030% or less. The O content may be 0%. However, from the viewpoint of a refining cost or the like, the O content may be set to 0.0005% or more or 0.0010% or more.

[0039] In the chemical composition of the cold-rolled steel sheet according to the present embodiment, the remainder excluding the above elements basically includes Fe and impurities. The impurities are elements that are incorporated from raw materials and/or in a steelmaking process and are allowed to be contained in a range in which the characteristics of the cold-rolled steel sheet according to the present embodiment are not clearly deteriorated.

[0040] On the other hand, for the purpose of improving various characteristics, the chemical composition of the cold-

rolled steel sheet according to the present embodiment may contain one or two or more selected from the group consisting of B, Mo, Nb, Cr, V, Co, Ni, Cu, W, Ta, Sn, Sb, As, Mg, Ca, Y, Zr, La, and Ce 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.

[0041]

B: 0% or More and 0.0100% or Less

Mo: 0% or More and 0.500% or Less

Cr: 0% or More and 2.000% or Less

Ni: 0% or More and 1.000% or Less

As: 0% or More and 0.050% or Less

[0042] B, Mo, Cr, Ni, 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 B content is set to 0.0001% or more, a Mo content, a Cr content, and a Ni content are each set to 0.010% or more, and an As content is set to 0.001% or more. More preferably, the B content is 0.0010% or more, the Mo content and the Cr content are each 0.100% 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 B content, the Mo content, the Cr content, the Ni content, and the As content, and the lower limits thereof are 0%.

[0043] On the other hand, even if B, Mo, Cr, Ni, and As are excessively contained, the effects of the above-described action are saturated, which is uneconomical. Therefore, in a case where these elements are contained, the B content is set to 0.0100% or less, the Mo content is set to 0.500% or less, the Cr content is set to 2.000% or less, the Ni content is set to 1.000% or less, and the As content is set to 0.050% or less. The B content is preferably 0.0030% or less, the Mo content is preferably 0.300% or less, the Cr content is preferably 1.000% or less, the Ni content is 0.500% or less, and the As content is preferably 0.030% or less.

[0044]

Nb: 0% or More and 0.200% or Less

V: 0% or More and 0.500% or Less

Cu: 0% or More and 1.000% or Less

W: 0% or More and 0.100% or Less

Ta: 0% or More and 0.100% or Less

[0045] Nb, V, Cu, W, and Ta are elements having an action of improving the strength of the steel sheet by precipitation hardening. Therefore, Nb, V, Cu, W, and Ta may be contained. In order to sufficiently obtain the above effect, each of a Nb content, a V content, a Cu content, a W content, and/or a Ta content is preferably 0.001% or more.

[0046] On the other hand, when these elements are excessively contained, the recrystallization temperature rises, the metallographic structure of the cold-rolled steel sheet becomes non-uniform, and the formability is impaired. Therefore, the Nb content is set to 0.200% or less, the V content is set to 0.500% or less, the Cu content is set to 1.000% or less, and the W content and the Ta content are each set to 0.100% or less.

Co: 0% or More and 0.500% or Less

[0047] 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.

[0048] 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.

[0049]

Ca: 0% or More and 0.040% or Less

Mg: 0% or More and 0.050% or Less

La: 0% or More and 0.050% or Less

Ce: 0% or More and 0.050% or Less

Y: 0% or More and 0.050% or Less

Zr: 0% or More and 0.050% or Less

Sb: 0% or More and 0.050% or Less

[0050] 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 in 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.

[0051] On the other hand, when these elements are excessively contained, ductility deteriorates. Therefore, a Ca content is set to 0.040% or less, and each of a Mg content, a La content, a Ce content, a Y content, a Zr content, and a Sb content is set to 0.050% or less.

Sn: 0% or More and 0.050% or Less

[0052] 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.

[0053] 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.

[0054] The chemical composition of the cold-rolled steel sheet according to the present embodiment can be obtained by the following method.

[0055] 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.

[0056] 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.

<Metallographic Structure (Microstructure)>

[0057] In the cold-rolled steel sheet according to the present embodiment, the metallographic structure at the position of 1/4 to 3/4 of the sheet thickness in the sheet thickness direction from the surface (when the sheet thickness is represented by t , a range of $t/4$ to $3t/4$) contains, 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.

[0058] 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.

[0059] 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 of the cold-rolled steel sheet 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.

[0060] As a structure other than retained austenite, one or two of martensite and tempered martensite are contained.

[0061] 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%.

[0062] 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.

[0063] 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.

[0064] The microstructure may contain ferrite and bainite in addition to retained austenite, martensite, and tempered martensite.

[0065] Ferrite is a soft structure and is a structure that improves the uniform elongation of the cold-rolled steel sheet and as a result, contributes to the improvement in workability. Therefore, in a case where ferrite is contained, ferrite may be contained so that a total amount of retained austenite and ferrite is 5% or more or more than 5%. On the other hand,

when the volume percentage of the ferrite is more than 3%, there are cases where the tensile strength of the steel sheet decreases. Therefore, the volume percentage of ferrite is preferably 3% or less.

[0066] Pearlite is a structure having strength intermediate between martensite and ferrite, but is a structure that has poor deformability and deteriorates workability. Therefore, it is preferable that pearlite is substantially not contained.

[0067] The reason for specifying the metallographic structure at the position of 1/4 to 3/4 of the sheet thickness from the surface centered at a position of 1/2 of the sheet thickness in the sheet thickness direction from the surface is that, in the cold-rolled steel sheet according to the present embodiment, the metallographic structure at this position is a representative structure of the steel sheet and has a strong correlation with the characteristics.

[0068] The volume percentage of each structure in the metallographic structure (microstructure) at the position of 1/4 to 3/4 of the sheet thickness in the sheet thickness direction from the surface of the cold-rolled steel sheet according to the present embodiment is measured as follows.

[0069] That is, the volume percentages of ferrite, bainite, martensite, tempered martensite, and pearlite are obtained by collecting a test piece from a random position in a rolling direction and in a width direction of the steel sheet, polishing a longitudinal section parallel to the rolling direction, and observing a structure revealed by nital etching in a range of 1/4 to 3/4 of the sheet thickness in the sheet thickness direction from the surface using a scanning electron microscope (SEM). In the SEM observation, five visual fields of $30\ \mu\text{m} \times 50\ \mu\text{m}$ 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. There is no microstructural change in a direction (steel sheet width direction) perpendicular to the rolling direction, area ratios of the longitudinal section parallel to the rolling direction are equal to volume percentages, and the area ratios obtained by the microstructural observation are each used as volume percentages.

[0070] 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.

[0071] Bainite and tempered martensite can be distinguished from each other by further carefully observing intragranular carbides.

[0072] 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.

[0073] 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 as martensite or retained austenite.

[0074] The volume percentage of retained austenite is obtained as described below: a test piece is collected from a random position in the steel sheet, a rolled surface is chemically polished from the surface of the steel sheet to a 1/4 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.

[0075] In addition, in the cold-rolled steel sheet according to the present embodiment, in the metallographic structure at the position of 1/4 to 3/4 of the sheet thickness in the sheet thickness direction from the surface, the P content at the prior γ grain boundaries is 10.0 mass% or less, and the Mn content at the prior γ grain boundaries is 10.0 mass% or less.

[0076] Segregation of Mn and P usually occurs when elements are distributed between a solid phase and a liquid phase during dendrite growth during solidification in a continuous casting step. When welding is performed on a steel sheet with segregation, a difference in hardness of martensite partially occurs (partial hardening) due to a difference in Mn content (difference in concentration) in a heat-affected zone of a welded part, resulting in a difference in joint strength after welding. It is presumed that this is because an M_s point changes depending on the difference in Mn content. In addition, cracking is likely to occur due to the co-segregation of Mn and P. Therefore, in order to increase the joint strength after welding, it is necessary to reduce the segregation of Mn and P. Therefore, in the cold-rolled steel sheet according to the present embodiment, the segregation of Mn and P is suppressed. More specifically, the P content at the prior γ grain boundaries is set to 10.0 mass% or less, and the Mn content at the prior γ grain boundaries is set to 10.0 mass% or less.

[0077] At the prior γ grain boundaries, when the P content is more than 10.0 mass% or the Mn content is more than 10.0 mass%, a welded joint obtained by welding decreases in strength due to the difference in hardness or cracking.

[0078] Each of the P content and the Mn content at the prior γ grain boundaries is preferably 8.0 mass% or less, and

more preferably 6.0 mass% or less.

[0079] In addition, lower limits of the P content and the Mn content at the prior γ grain boundaries are not limited. However, since both P and Mn are elements that segregate at the grain boundaries, it is not easy to set the P content to be equal to or less than 80 times the P content of the base metal in the case of P, and it is difficult in principle to suppress the Mn content to 1.01 times or less the Mn content of the base metal in the case of Mn. Therefore, taking these into consideration, the P content and the Mn content at the prior γ grain boundaries may each be 3.6% or more.

[0080] The reason for specifying a segregation degree in the metallographic structure at the position of 1/4 to 3/4 of the sheet thickness in the sheet thickness direction from the surface centered at the position of 1/2 of the sheet thickness in the sheet thickness direction from the surface is that the segregation degree at this position is larger than those of other positions, and an effect of reducing segregation in a region including that point is to be evaluated.

[0081] In the related art, although an influence of P and Mn on macro and semi-macro segregation has been evaluated, an influence on the segregation to the prior γ grain boundaries as described above has not been clarified. It is a new finding obtained by the present inventors that a joint having high joint strength can be obtained by controlling the P content and the Mn content at the prior γ grain boundaries.

[0082] The P content and the Mn content at the prior γ grain boundaries are measured by the following method.

[0083] A test piece for an Auger test having a size shown in FIG. 1 is cut out from a position of 1/4 to 3/4 of the sheet thickness from the surface, centered at the position of 1/2 of the sheet thickness from the surface of the steel sheet. This test piece is immersed in an aqueous solution of ammonium thiocyanate having a concentration of 20 mass% for 48 hours. An impact test is conducted on the test piece after the immersion to obtain a fracture surface. In the impact test, the test piece is cooled with liquid nitrogen and is then fractured by being hit with a hammer in a vacuum. Thereby, the fracture surface becomes a grain boundary (prior γ grain boundary) fracture surface, so that the P content and the Mn content are measured by conducting Auger electron spectroscopy on this fracture surface. Accordingly, the P content and the Mn content at the prior γ grain boundaries are obtained.

[0084] A measuring device is not particularly limited, but the measurement is performed using, for example, JAMP-9500F manufactured by JEOL, Ltd. In addition, during the measurement, a portion on the grain boundary fracture surface in which no precipitate is present is measured at least three times, and AES peaks of P and Mn are measured. The AES peak intensities are subjected to sensitivity correction by corresponding relative sensitivity factors (RSF) to obtain grain boundary segregation concentrations with reference to Non-Patent Document (Analytic Chemistry, vol.35 (1986)).

[0085] A reduction in the P content and the Mn content at the prior γ grain boundaries (a reduction of segregation to the prior γ grain boundaries) can also be effectively achieved by performing a large reduction during hot rolling to refine grains, as described later. Therefore, in the cold-rolled steel sheet according to the present embodiment, a prior γ grain size (average grain size) is preferably 15 μm or less.

[0086] The prior γ grain size can be measured by the following method.

[0087] A test piece is collected from any position in a rolling direction and a width direction of the steel sheet, a longitudinal section parallel to the rolling direction is polished, and a structure revealed using a saturated aqueous solution of picric acid from a range of 1/4 to 3/4 of the sheet thickness in the sheet thickness direction from the surface is observed using an optical microscope. In the structure revealed by the saturated aqueous solution of picric acid, a mesh-like black line is determined to be the prior γ grain boundary. In a case where no mesh-like black line appears when the saturated aqueous solution of picric acid is used, a surfactant is added or a temperature of immersion in the saturated aqueous solution of picric acid is changed to about 20°C to 80°C to allow a mesh-like black line to be revealed. In the observation with the optical microscope, any magnification of 200 to 1000-fold is selected, and an image of the structure is acquired. Three images including at least 200 or more grains are photographed, and an average grain size of the prior γ (austenite) grain sizes is measured in the photographed images using a point calculation method.

[0088] The measurement method of the prior γ grain size is not limited to the above method, and the prior γ grain size can also be measured by using an inverse analysis of prior austenite using scanning electron microscope-electron back scattering diffraction pattern (SEM-EBSD).

[0089] The cold-rolled steel sheet according to the present embodiment described above may have a coating layer containing zinc, aluminum, magnesium, or an alloy of these metals on the surface. The coating layer may be substantially made of zinc, aluminum, magnesium, or an alloy of these metals. The presence of the coating layer on the surface of the steel sheet improves corrosion resistance. The coating layer may be a known coating layer.

[0090] For example, in a case where the steel sheet is used under a corrosive environment, there may be cases where the sheet thickness cannot be reduced to a certain sheet thickness or less even though high-strengthening is achieved because of concerns about perforation and the like. 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. In a case where coating layer containing zinc, aluminum, magnesium, or an alloy of these metals is provided on the surface, the corrosion resistance is improved, and an applicable range is widened, which is preferable.

[0091] In a case where the steel sheet has a coating layer (for example, a plating layer) on the surface, the "surface"

in the "position of 1/4 to 3/4 of the thickness from the surface of the steel sheet" means a surface of the base metal excluding the coating layer.

[0092] The sheet thickness of the cold-rolled steel sheet according to the present embodiment is not limited to a specific range, but is preferably 1.0 to 2.0 mm in consideration of strength, versatility, and manufacturability.

<Tensile Strength>

[0093] In the cold-rolled steel sheet according to the present embodiment, as the strength that contributes to a weight reduction of vehicle bodies of vehicles, the tensile strength (TS) is set to 1,310 MPa or more. 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.

[0094] 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.

[Welded Joint]

[0095] A welded joint according to the present embodiment is obtained by joining the cold-rolled steel sheet according to the present embodiment to another steel sheet (which may be the cold-rolled steel sheet according to the present embodiment) by welding. Therefore, the welded joint according to the present embodiment is a welded joint in which a plurality of steel sheets are joined together, and at least one steel sheet is the cold-rolled steel sheet according to the present embodiment described above.

[0096] In the welded joint according to the present embodiment, the steel sheets are joined through a welded part, and in a case where the welding is spot welding, the steel sheets are joined through a spot-welded part.

[Manufacturing Method]

[0097] 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.

[0098] Specifically, the cold-rolled steel sheet according to the present embodiment can be manufactured by a manufacturing method including the following steps (I) to (VIII):

(I) a continuous casting step of obtaining a slab having a predetermined chemical composition by continuous casting;

(II) a breakdown step of reducing a thickness of the slab by performing a reduction at a reduction ratio of 30% to 60% in a temperature range of 850°C to 1,000°C;

(III) a high-temperature heat treatment step of heating the slab after the breakdown step to 1,000°C to 1,300°C, holding the slab for 5 to 20 hours, and cooling the slab;

(IV) a hot rolling step of performing hot rolling on the slab after the high-temperature heat treatment step to obtain a hot-rolled steel sheet;

(V) a coiling step of coiling the hot-rolled steel sheet in a temperature range of 400°C to 650°C;

(VI) a cold rolling step of pickling the hot-rolled steel sheet after the coiling step and performing cold rolling on the hot-rolled steel sheet at a reduction ratio of 20% to 80% to obtain a cold-rolled steel sheet;

(VII) an annealing step of heating the cold-rolled steel sheet to an annealing temperature of higher than Ac3°C at an average temperature rising rate of 2 °C/sec or faster, holding the cold-rolled steel sheet at the annealing temperature for 60 to 300 seconds, and cooling the cold-rolled steel sheet to 250°C or lower at an average cooling rate of 10 °C/sec or faster; and

(VIII) a holding step of holding the cold-rolled steel sheet after the annealing step at 150°C to 400°C for 500 seconds or shorter.

[0099] In addition, the welded joint according to the present embodiment can be obtained by a manufacturing method further including the following step:

(IX) a welding step of welding the cold-rolled steel sheet after the holding step to another steel sheet.

[0100] Hereinafter, preferable conditions for each step will be described.

<Continuous Casting Step>

[0101] In the continuous casting step, the slab having the predetermined chemical composition (the same chemical composition as the cold-rolled steel sheet according to the present embodiment because the chemical composition does

not substantially change in the subsequent steps) is obtained by continuous casting.

<Breakdown (BD) Step>

<High-Temperature Heat Treatment (SP Treatment) Step>

[0102] In the breakdown step, the slab obtained in the continuous casting step is reduced in thickness by being subjected to the reduction (BD) at a reduction ratio of 30% to 60% in a temperature range of 850°C to 1,000°C. When a temperature of the slab obtained in the continuous casting step is lower than 850°C, the reduction is performed after heating. When the temperature of the slab is in a range of 850°C to 1,000°C, heating does not have to be performed.

[0103] Thereafter, in the high-temperature heat treatment step, the slab after the breakdown step is heated to 1,000°C to 1,300°C, is held at the temperature for 5 to 20 hours (SP treatment), and is then cooled.

[0104] The level of segregation of Mn and P is lowered by the SP treatment. However, attempts to reduce the segregation of Mn and P only by the SP treatment, a significantly high temperature or long-time processing is required. Therefore, in the manufacturing method of the cold-rolled steel sheet according to the present embodiment, segregation is sufficiently reduced by performing the BD before the SP treatment.

[0105] By performing the BD, effects such as an increase in a diffusion constant and a decrease in a segregation zone thickness can be obtained. Therefore, by performing the SP treatment after performing the BD, the level of segregation of Mn and P can be lowered at a temperature and a time within a practical range. When any one of the above conditions is not satisfied, sufficient effects cannot be obtained.

[0106] In the related art, in order to reduce macrosegregation or semi-macrosegregation, a BD step or an SP step has been performed alone. However, an effect of the BD step or the SP step on reducing the P content or the Mn content at the prior γ grain boundaries was not clear. In addition, it was not known that by combining the BD step and the SP step and further performing a large reduction by hot rolling as described later, it is possible to reduce the P content and the Mn content at the prior γ grain boundaries to a predetermined range compared to a case where the BD step or the SP step is performed alone. Therefore, a combination of these steps has not usually been performed.

<Hot Rolling Step>

[0107] In the hot rolling step, the slab after the BD and the SP treatment is heated and hot-rolled to obtain a hot-rolled steel sheet.

[0108] A heating temperature prior to the hot rolling is not limited. However, when the temperature is lower than 1,100°C, there is a concern that carbides and sulfides generated between the casting and the SP treatment step are not solubilized and become coarse and a grain size during annealing becomes coarse. Therefore, the heating temperature is preferably 1,100°C or higher. An upper limit of the heating temperature is not particularly specified, but is generally 1,300°C or lower.

[0109] In the hot rolling step, recrystallization is utilized to refine γ and suppress P segregation to grain boundaries.

[0110] Therefore, in the hot rolling step, rough rolling and finish rolling are usually performed. In a case where the finish rolling is performed using a rolling mill having four or more stands and an initial stand and a last stand are respectively referred to as a first stand and an nth stand, a sheet thickness reduction ratio in each stand from a (n-3)th stand to the nth stand is set to 30% or more, and a rolling temperature in the last stand (nth stand) is set to 900°C or lower. That is, for example, in a rolling mill having seven stands, sheet thickness reduction ratios in a fourth stand, a fifth stand, a sixth stand, and a seventh stand are each set to 30% or more, and a rolling temperature in the seventh stand is set to 900°C or lower. In this finish rolling, an austenite grain size is refined by recrystallization during the rolling, and this refined grain boundary is used as a diffusion path to promote the diffusion of Mn, P, and the like and the segregation is reduced.

[0111] When the sheet thickness reduction ratio in any of the stands is less than 30%, or when the rolling temperature in the nth stand is higher than 900°C, a hot-rolled structure becomes coarse and a duplex-grain structure, and a structure after the annealing step described later also becomes coarse. When a hot rolling completion temperature is lower than 830°C, a rolling reaction force increases and it becomes difficult to stably obtain a target sheet thickness. Therefore, a rolling temperature in the last stand is preferably 830°C or higher. In addition, even if the reduction ratio is set to be larger than 50%, an effect of the refinement is saturated, and an equipment load excessively increases due to an increase in rolling load. Therefore, the sheet thickness reduction ratio in each of the (n-3)th stand to the nth stand is preferably set to 50% or less.

[0112] In addition, the finish rolling is performed using the rolling mill having four or more stands so that continuous rolling with a short interpass time for the last four passes of the rolling is performed. This is because, when the interpass time is long, even if the reduction is performed at a large sheet thickness reduction ratio, strain tends to recover between passes and does not sufficiently accumulate.

<Coiling Step>

[0113] In the coiling step, the hot-rolled steel sheet after the hot rolling step is coiled at a coiling temperature of 400°C or higher and 650°C or lower.

[0114] When the coiling temperature is higher than 650°C, an internal oxide layer is formed and a pickling property deteriorates.

[0115] On the other hand, when the coiling temperature is lower than 400°C, the strength of the steel sheet becomes excessive, a cold rolling load becomes excessive, and productivity deteriorates.

<Cold Rolling Step>

[0116] In the cold rolling step, the hot-rolled steel sheet after the coiling step is pickled under known conditions and is then cold-rolled at a reduction ratio (sheet thickness reduction ratio) of 20% to 80% to obtain a cold-rolled steel sheet.

[0117] When the sheet thickness reduction ratio is less than 20%, strain accumulation in the steel sheet becomes insufficient, austenite nucleation sites become non-uniform, and the segregation degree of Mn and P at the prior γ grain boundaries increases.

[0118] On the other hand, when the sheet thickness reduction ratio is more than 80%, the cold rolling load becomes excessive, and the productivity deteriorates.

[0119] Therefore, the sheet thickness reduction ratio is set to 20% or more and 80% or less. The sheet thickness reduction ratio is preferably 30% or more and 80% or less. A cold rolling method is not limited, and the number of rolling passes and the reduction ratio for each pass may be set as appropriate.

<Annealing Step>

[0120] In the annealing step, the cold-rolled steel sheet obtained in the cold rolling step is heated to an annealing temperature of higher than A_{c3} °C at an average temperature rising rate of 2 °C/sec or faster, is held at this annealing temperature for 60 to 300 seconds, and is, after being held, cooled to 250°C or lower at an average cooling rate of 10 °C/sec or faster.

[0121] When the average temperature rising rate is slower than 2 °C/sec, the productivity decreases, the grain size becomes coarse, and the segregation degree of Mn and P at the prior γ grain boundaries increases, which is not preferable.

[0122] When the annealing temperature is A_{c3} °C or lower or a holding time is shorter than 60 seconds, γ transformation is insufficient, and there are cases where a target structure cannot be obtained after the annealing step. On the other hand, when an annealing time is longer than 300 seconds, the productivity decreases.

[0123] When the average cooling rate is slower than 10 °C/sec or a cooling stop temperature is higher than 250°C, ferrite and bainite are generated, and there is a concern that a target metallographic structure cannot be obtained. On the other hand, setting the cooling stop temperature to lower than 150°C not only requires significant investment in equipment, but also saturates an effect of setting the cooling stop temperature to lower than 150°C. Therefore, the cooling stop temperature is preferably set to 150°C or higher.

[0124] A temperature (°C) at the A_{c3} point can be obtained by the following method.

$$Ac3 = 910 - (203 \times C^{1/2}) + 44.7 \times Si - 30 \times Mn + 700 \times P - 20 \times Cu - 15.2 \times Ni - 11 \times Cr + 31.5 \times Mo + 400 \times Ti + 104 \times V + 120 \times Al$$

[0125] In the annealing step, a coating layer containing zinc, aluminum, magnesium, or an alloy of these metals may be formed on the surface of the steel sheet from the viewpoint of increasing the corrosion resistance of the steel sheet. For example, during the cooling after the holding, the steel sheet may be immersed in a plating bath to form a hot-dip plating within a range in which the above average cooling rate can be satisfied. In addition, the hot-dip plating may be heated to a predetermined temperature and alloyed to obtain an alloyed hot-dip plating. In addition, the plating layer may further contain Fe, Al, Mg, Mn, Si, Cr, Ni, Cu, or the like. Any of the above methods may be used for the plating layer for the purpose of increasing corrosion resistance. As plating conditions and alloying conditions, known conditions may be applied depending on a composition of the plating.

<Holding Step>

[0126] In the holding step, the cold-rolled steel sheet after the annealing step is held at 150°C to 400°C for 500 seconds or shorter.

[0127] By the holding step, a portion or the entirety of martensite is tempered and becomes tempered martensite.

When a holding temperature is lower than 150°C, martensite is not sufficiently tempered, and the effect cannot be sufficiently obtained.

[0128] When the holding temperature is higher than 400°C, a dislocation density in tempered martensite decreases, which may lead to a decrease in tensile strength.

[0129] When the holding time is longer than 500 seconds, the tensile strength decreases, and the productivity decreases.

[0130] A lower limit of the holding time is not limited, but the holding time is preferably set to 100 seconds or longer in a case where the metallographic structure primarily contains tempered martensite.

[0131] When the temperature of the cold-rolled steel sheet drops to lower than 150°C before the holding step, heating may be performed as necessary.

<Welding Step>

[0132] In the welding step, the cold-rolled steel sheet after the holding step is welded to other steel sheets. Other steel sheets are not limited, and may be or may not be the cold-rolled steel sheet according to the present embodiment. In addition, the welding may be performed to join three or more steel sheets by performing the welding a plurality of times.

[0133] A welding method is not limited, but spot welding is preferable in a case where an application to vehicle components is considered.

[Examples]

[0134] Slabs (kinds of steel A to X) having the chemical composition shown in Tables 1-1 and 1-2 (unit is mass%, remainder includes Fe and impurities) were manufactured by continuous casting.

[0135] These slabs were subjected to breakdown by being heated to the temperature shown in Table 2-1 and reduced in thickness by a reduction at the reduction ratio shown in Table 2-1. Thereafter, the slabs were subjected to an SP treatment by being heated to the temperature shown in Table 2-1 and held.

[0136] The slabs after the SP treatment were heated to 1, 100°C to 1,300°C, hot-rolled, and coiled at the coiling temperature shown in Table 2-2 to obtain hot-rolled steel sheets. During the hot rolling, finish rolling was performed using a hot rolling mill having seven stands, and reduction ratios from the third to the last stand to the last stand and a rolling temperature in the last stand were set as shown in Table 2-2.

[0137] These hot-rolled steel sheets were pickled under known conditions and then cold-rolled at the reduction ratio shown in Table 2-2 to obtain cold-rolled steel sheets having a sheet thickness of 1.0 to 2.0 mm. However, some of the hot-rolled steel sheets had high strength and could not be cold-rolled.

[0138] The obtained cold-rolled steel sheets were annealed under the conditions of Table 2-3 and then held under the conditions of Table 2-3.

[0139] Furthermore, some of the cold-rolled steel sheets were heated or cooled to (galvanizing bath temperature - 40)°C to (galvanizing bath temperature + 50)°C in the middle of the annealing (cooling stage) and immersed in the galvanizing bath to be galvanized (examples with Present in the field of Presence of absence of plating in the tables). In addition, some of the galvanized cold-rolled steel sheets were further heated to a temperature range of 470°C to 550°C to be alloyed (examples of Present in the field of Presence or absence of alloying in the tables).

[Table 1-1]

Kind of steel	(mass%, remainder: Fe and impurities)														
	C	Si	Mn	P	S	Al	Ti	N	O	B	Mo	Nb	Cr	V	Co
A	0.263	1.46	3.0	0.0377	0.0017	0.030	0.080	0.0030	0.0011						
B	0.291	1.00	1.5	0.0119	0.0002	0.057	0.031	0.0009	0.0006						
C	0.392	2.42	1.3	0.0312	0.0065	0.066	0.008	0.0083	0.0022						
D	0.419	1.41	2.2	0.0332	0.0017	0.024	0.079	0.0094	0.0057						
E	0.309	1.65	3.1	0.0040	0.0041	0.059	0.038	0.0025	0.0026						
F	0.332	1.51	2.4	0.0203	0.0080	0.022	0.006	0.0070	0.0021						
G	0.404	1.73	2.7	0.0058	0.0008	0.019	0.023	0.0043	0.0053						
H	0.378	1.98	2.3	0.0040	0.0069	0.004	0.046	0.0040	0.0029						
I	0.223	1.20	1.0	0.0147	0.0043	0.081	0.042	0.0058	0.0036						
J	0.426	0.35	3.4	0.0338	0.0075	0.072	0.049	0.0075	0.0040						
K	0.211	1.02	0.9	0.0276	0.0087	0.089	0.013	0.0090	0.0003						
L	0.279	0.67	1.8	0.0015	0.0024	0.036	0.065	0.0052	0.0042	0.0041					
M	0.313	0.16	1.6	0.0218	0.0028	0.013	0.058	0.0006	0.0044		0.182		0.559		0.237
N	0.329	0.14	1.3	0.0067	0.0066	0.014	0.089	0.0085	0.0051			0.198	0.262		0.408
O	0.356	2.06	3.2	0.0256	0.0057	0.094	0.017	0.0063	0.0015			0.097		0.348	
P	0.290	0.71	3.5	0.0209	0.0086	0.089	0.096	0.0050	0.0042						0.159
Q	0.260	0.97	3.0	0.0223	0.0050	0.017	0.065	0.0038	0.0007						
R	0.342	1.92	1.8	0.0176	0.0090	0.003	0.068	0.0059	0.0022		0.210		0.974		
S	0.360	0.40	1.7	0.0257	0.0021	0.034	0.090	0.0009	0.0057	0.0073					
T	0.329	0.14	1.3	0.0067	0.0066	0.014	0.048	0.0085	0.0016			0.006		0.372	
U	0.236	1.21	2.4	0.0279	0.0002	0.082	0.084	0.0071	0.0020						
V	0.191	0.17	0.7	0.0331	0.0078	0.022	0.076	0.0017	0.0053						
W	0.458	1.49	2.1	0.0173	0.0057	0.050	0.017	0.0009	0.0048						
X	0.228	1.03	0.5	0.0286	0.0019	0.043	0.004	0.0051	0.0009						

[Table 1-2]

Kind of steel	(mass%, remainder: Fe and impurities)													Ac3 point (°C)
	Ni	Cu	w	Ta	Sn	56	As	Mg	Ca	Y	Zr	La	Ce	
A														843
B														828
C														885
D														833
E														803
F														808
G														793
H														826
I														875
J														743
K														871
L														810
M														795
N		0.369												793
O														857
P	0.326													786
Q						0.045	0.035	0.041	0.025	0.025				803
R			0.022	0.031	0.044						0.010	0.009	0.006	859
S					0.049					0.029	0.042			813
T						0.023	0.042				0.029	0.003	0.007	825
U				0.095			0.022	0.021				0.044	0.046	856
V														864
W														801
X														871

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[Table 2-1]

	No.	Kind of steel	Classification	Breakdown (BD) step		SP treatment step	
				Slab heating temperature [°C]	Breakdown reduction ratio [%]	Heating temperature [°C]	Holding time [hr]
5	1	A	Example	888	48	1,249	19
	2	B	Example	905	42	1,090	9
10	3	C	Example	965	59	1,073	17
	4	D	Example	992	39	1,158	11
	5	E	Example	878	56	1,010	9
15	6	F	Example	929	48	1,182	13
	7	G	Example	972	51	1,213	7
	8	H	Example	957	54	1,172	7
	9	I	Example	864	44	1,046	11
20	10	J	Example	985	34	1,288	18
	11	K	Example	856	42	1,029	15
	12	L	Example	897	38	1,128	6
25	13	M	Example	918	32	1,106	13
	14	N	Example	931	35	1,235	19
	15	O	Example	943	55	1,267	15
	16	P	Example	929	31	1,119	17
30	17	Q	Example	878	44	1,259	8
	18	A	Example	938	51	1,252	13
	19	S	Example	905	36	1,093	11
35	20	T	Example	960	53	1,290	15
	21	U	Example	867	44	1,189	18
	22	A	Example	973	59	1,176	6
40	23	B	Example	860	49	1,023	11
	24	C	Example	942	33	1,065	8
	25	D	Example	911	37	1,009	15
	26	E	Example	983	46	1,227	17
45	27	F	Example	889	57	1,215	14
	28	G	Example	897	39	1,158	6
	29	H	Example	952	41	1,050	19
50	30	I	Example	996	55	1,137	9
	31	V	Compative Example	888	48	1,249	19
	32	<u>W</u>	Comparative Example	905	42	1,090	9
	33	<u>X</u>	Comparative Example	965	59	1,073	17
55	34	J	Compative Example	1006	38	1,100	12
	35	K	Comparative Example	953	29	1,013	16
	36	L	Compative Example	983	33	<u>991</u>	9

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(continued)

No.	Kind of steel	Classification	Breakdown (BD) step		SP treatment step	
			Slab heating temperature [°C]	Breakdown reduction ratio [%]	Heating temperature [°C]	Holding time [hr]
37	M	Comparative Example	934	54	1,210	<u>3</u>
38	N	Comparative Example	976	34	1,272	7
39	O	Comparative Example	917	39	1,014	19
40	P	Comparative Example	896	58	1,065	6
41	Q	Comparative Example	928	55	1,160	6
42	R	Comparative Example	963	48	1,036	15
43	S	Comparative Example	856	55	1,293	15
44	T	Comparative Example	978	48	1,107	8
45	U	Comparative Example	994	32	1,244	10
46	A	Comparative Example	974	57	1,258	12
47	B	Comparative Example	890	52	1,151	17

[Table 2-2]

No.	Kind of steel	Classification	Hot rolling step						Coldrolling step
			(n-3)th stand sheet thickness reduction ratio [%]	(n-2)th stand sheet thickness reduction ratio [%]	(n-1)th stand sheet thickness reduction ratio [%]	Last stand (nth stand) sheet thickness reduction ratio [%]	Last stand rolling temperature [°C]	Coiling temperature [°C]	Reduction ratio [%]
1	A	Example	33	36	36	46	869	442	65
2	B	Example	30	41	32	36	838	422	4B
3	C	Example	43	43	47	44	895	490	57
4	D	Example	40	39	49	46	846	637	52
5	E	Example	38	40	33	37	840	505	73
6	F	Example	46	34	44	31	857	483	61
7	G	Example	32	34	39	34	873	618	27
8	H	Example	44	31	38	39	842	520	71
9	I	Example	39	46	42	49	866	548	40
10	J	Example	45	44	45	40	883	564	21
11	K	Example	47	48	48	32	887	408	31
12	L	Example	35	37	40	43	859	573	30
13	M	Example	36	32	31	42	852	584	42
14	N	Example	49	45	34	48	896	610	77
15	O	Example	41	49	42	33	880	400	35
16	P	Example	37	49	42	33	856	439	35

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(continued)

No.	Kind of steel	Classification	Hot rolling step						Coldrolling step
			(n-3)th stand sheet thickness reduction ratio [%]	(n-2)th stand sheet thickness reduction ratio [%]	(n-1)th stand sheet thickness reduction ratio [%]	Last stand (nth stand) sheet thickness reduction ratio [%]	Last stand rolling temperature [°C]	Coiling temperature [°C]	Reduction ratio [%]
17	Q	Example	44	33	48	31	845	422	46
18	R	Example	34	43	47	32	839	634	51
19	S	Example	41	37	32	43	885	415	63
20	T	Example	31	45	36	35	850	522	23
21	U	Example	33	48	41	44	888	605	29
22	A	Example	48	39	34	47	868	569	73
23	B	Example	36	46	40	37	860	462	76
24	C	Example	47	31	31	40	894	585	54
25	D	Example	46	42	49	45	863	482	41
26	E	Example	34	36	38	36	896	548	37
27	F	Example	39	39	37	49	840	516	67
28	G	Example	50	44	35	47	834	494	70
29	H	Example	39	33	45	39	879	629	57
30	I	Example	43	35	43	41	892	561	27
31	<u>V</u>	Comparative Example	33	36	36	46	869	442	65
32	<u>W</u>	Comparative Example	30	41	32	36	838	422	Hot-rolled steel sheet has high strength and cannot be cold-rolled
33	<u>X</u>	Comparative Example	43	43	47	44	876	490	57
34	J	Comparative Example	49	43	32	32	864	621	36
35	K	Comparative Example	30	49	47	43	892	511	48
36	L	Comparative Example	44	40	43	32	873	575	46
37	M	Comparative Example	34	35	37	36	867	435	28
38	N	Comparative Example	40	44	41	29	845	608	52

(continued)

No.	Kind of steel	Classification	Hot rolling step						Coldrolling step
			(n-3)th stand sheet thickness reduction ratio [%]	(n-2)th stand sheet thickness reduction ratio [%]	(n-1)th stand sheet thickness reduction ratio [%]	Last stand (nth stand) sheet thickness reduction ratio [%]	Last stand rolling temperature [°C]	Coiling temperature [°C]	Reduction ratio [%]
39	O	Comparative Example	33	48	38	47	923	470	51
40	P	Comparative Example	25	28	19	45	880	610	65
41	Q	Comparative Example	41	40	49	35	836	<u>395</u>	Hot-rolled steel sheet has high strength and cannot be cold-rolled
42	R	Comparative Example	37	46	42	44	865	547	<u>18</u>
43	S	Comparative Example	45	33	34	34	S74	583	70
44	T	Comparative Example	36	42	44	35	889	456	61
45	U	Comparative Example	37	47	37	48	834	563	37
46	A	Comparative Example	33	35	33	37	852	622	32
47	B	Comparative Example	43	34	40	33	863	468	73

[Table 2-3]

No.	Kind of steel	Classification	Ann aealing step						Holding step		Present or absence of plating	Present or absence of alloying	Note
			Average temperature rising rate [°C/sec]	Annealing temperature [°C]	Holding time (sec)	Average cooling rate [°C/sec]	Cooling stop temperature [°C]	Holding temperature [°C]	Holding time (sec)				
1	A	Example	29	852	121	33	152	240	333	Absent	Absent	Absent	843
2	B	Example	5	835	147	38	189	272	259	Absent	Absent	Absent	828
3	C	Example	7	890	244	21	179	229	488	Present	Absent	Absent	885
4	D	Example	17	837	287	27	219	305	222	Absent	Absent	Absent	833
5	E	Example	24	806	105	14	200	339	450	Present	Present	Present	803
6	F	Example	4	812	187	35	159	292	342	Absent	Absent	Absent	808
7	G	Example	19	796	256	22	232	397	376	Absent	Absent	Absent	793
8	H	Example	11	834	231	18	244	197	416	Present	Present	Present	826
9	I	Example	26	880	82	28	208	253	290	Absent	Absent	Absent	875
10	J	Example	14	760	277	24	211	376	154	Present	Absent	Absent	743
11	K	Example	13	872	70	12	237	321	262	Present	Present	Present	871
12	L	Example	8	820	136	19	225	356	206	Present	Present	Present	810
13	M	Example	27	812	168	15	175	166	124	Present	Present	Present	795
14	N	Example	22	831	189	37	195	206	162	Absent	Absent	Absent	793
15	O	Example	16	867	210	31	169	182	429	Absent	Absent	Absent	857
16	P	Example	7	845	102	30	206	203	115	Absent	Absent	Absent	786
17	Q	Example	5	804	210	38	245	368	494	Absent	Absent	Absent	803
18	R	Example	29	862	243	36	174	308	301	Absent	Absent	Absent	859
19	S	Example	23	824	203	15	192	189	214	Present	Present	Present	813
20	T	Example	16	836	261	12	211	391	238	Present	Present	Present	825
21	U	Example	4	860	174	13	154	293	490	Present	Present	Present	856
22	A	Example	18	853	163	28	217	358	149	Absent	Absent	Absent	843

(continued)

No.	Kind of steel	Classification	Ann ealing step						Holding step		Present or absence of plating	Present or absence of alloying	Note
			Average temperature rising rate [°C/sec]	Annealing temperature [°C]	Holding time (sec)	Average cooling rate [°C/sec]	Cooling stop temperature [°C]	Holding temperature [°C]	Holding time (sec)				
23	B	Example	10	836	227	17	242	170	436	Present	Absent	828	
24	C	Example	9	887	148	29	168	228	383	Absent	Absent	885	
25	D	Example	22	841	270	23	226	271	265	Present	Absent	833	
26	E	Example	14	836	72	25	202	326	402	Absent	Absent	803	
27	F	Example	20	827	133	35	182	167	175	Absent	Absent	808	
28	G	Example	26	844	90	33	158	345	113	Absent	Absent	793	
29	H	Example	13	865	116	19	235	237	203	Present	Present	826	
30	I	Example	27	880	293	22	187	261	327	Absent	Absent	875	
31	V _	Comparative Example	29	879	213	33	152	316	343	Absent	Absent	864	
32	W _	Comparative Example	Hot-rolled steel sheet has high strength and cannot be cold-rolled										801
33	X _	Comparitive Example	7	880	141	21	179	371	458	Present	Absent	871	
34	J	Comparitive Example	13	846	139	28	210	269	488	Absent	Absent	743	
35	K	Comparative Example	19	874	286	11	155	187	233	Present	Present	871	
36	L	Comparitive Example	17	821	288	21	242	181	485	Absent	Absent	810	
37	M	Comparitive Example	27	811	117	13	174	278	382	Present	Present	795	
38	N	Comparitive Example	19	802	138	39	224	326	453	Absent	Absent	793	

(continued)

No.	Kind of steel	Classification	Ann aealing step						Holding step		Present or absence of plating	Present or absence of alloying	Note
			Average temperature rising rate [°C/sec]	Annealing temperature [°C]	Holding time (sec)	Average cooling rate [°C/sec]	Cooling stop temperature [°C]	Holding temperature [°C]	Holding time (sec)				
39	O	Comparative Example	29	862	85	24	161	371	301	Present	Absent	857	
40	P	Comparative Example	24	881	99	28	207	288	353	Absent	Absent	786	
41	Q	Comparative Example	Hot-rolled steel sheet has high strength and cannot be cold-rolled										803
42	R	Comparative Example	15	865	238	17	159	196	409	Present	Present	859	
43	S	Comparative Example	1 _	825	255	25	202	256	245	Absent	Absent	813	
44	T	Comparative Example	9	802 _	174	is	197	391	140	Present	Absent	825	
45	U	Comparative Example	9	869	152	9	243	382	427	Present	Present	856	
46	A	Comparative Example	7	852	194	32	252 _	383	468	Absent	Absent	843	
47	B	Comparative Example	12	831	67	29	180	427 _	266	Absent	Absent	828	

[0140] In the obtained cold-rolled steel sheet, a metallographic structure at a position of $t/4$ to $3t/4$ is observed in the above-described manner, a total volume percentage of martensite and tempered martensite, and volume percentages of retained austenite, ferrite, bainite, and pearlite were obtained.

[0141] In addition, in the metallographic structure at the position of $t/4$ to $3t/4$, a P content and a Mn content at prior γ grain boundaries were measured in the above-described manner.

[0142] In addition, a JIS No. 5 test piece was collected from the obtained cold-rolled steel sheets at a right angle to a rolling direction, and a tensile strength was measured according to JIS Z 2241: 2011.

[0143] In addition, spot welding was performed on a sheet assembly in which two obtained cold-rolled steel sheets were stacked, and joint characteristics were evaluated.

[0144] For the welding, a servo motor pressure type single-phase AC welder (power supply frequency: 50 Hz) was used, and as an electrode, a Cr-Cu DR type electrode having a radius of curvature of 40 mm at a tip and a diameter of 6 mm at the tip was used.

[0145] Welding conditions were a weld force of 440 kgf, an energization time of 0.28 sec, and a hold time of 0.1 sec. A welding current was set under a condition in which a nugget diameter of $5\sqrt{t}$ could be obtained.

[0146] Then, a cross tensile test was conducted on the manufactured joint according to JIS Z 3137 (1999) (performed under each condition $n = 2$).

[0147] Compared to steel sheets without reducing segregation in the related art (steel sheets having the same chemical composition for each steel sheet and to which the same manufacturing conditions were applied except for the breakdown step, the high-temperature heat treatment step, and the hot rolling step), those with joint characteristics improved by 5% or more were evaluated as C (Fair), those improved by 10% or more were evaluated as B (Good), those improved by 20% or more were evaluated as A (Excellent), and those with no improvement were evaluated as D (NG).

[Table 3]

No.	Kind of steel	Classification	Structure (t/4 to 3t/4)					Tensile strength [MPa]	Prior γ grain size [μm]	Segregation (t/4 to 3t/4)		Determination of joint characteristics
			Total of martensite and tempered martensite [volume%]	Retained γ [volume%]	Ferrite [volume%]	Bainite [volume%]	Pearlite [volume%]			P content at prior γ grain boundaries [mass%]	Mn content at prior γ grain boundaries [mass%]	
1	A	Example	94.2	0.3	2.5	3.0	0.0	1,722	11	3.7	5.6	A
2	B	Example	91.5	4.8	1.4	2.3	0.0	1,642	13	6.6	7.9	C
3	C	Example	94.7	2.4	2.1	0.8	0.0	1,722	10	6.7	8.2	B
4	D	Example	92.9	2.0	1.1	4.0	0.0	1,920	8	9.3	9.7	C
5	B	Example	95.9	1.2	1.5	1.4	0.0	1,733	9	4.8	6.3	A
6	F	Example	90.9	4.5	1.9	2.7	0.0	1,823	11	5.4	6.7	A
7	G	Example	96.5	2.1	0.0	1.4	0.0	1,443	13	8.5	9.8	C
8	H	Example	90.5	6.5	2.1	0.9	0.0	1,807	7	7.8	9.1	C
9	I	Example	94.9	1.1	1.6	2.4	0.0	1,547	8	4.5	6	B
10	J	Example	93.3	2.2	2.0	2.5	0.0	1,622	11	8.5	9.8	C
11	K	Example	97.1	0.7	1.8	0.4	0.0	1,537	10	4.4	5.6	A
12	L	Example	92.1	6.2	0.7	1.0	0.0	1,530	10	7.4	8.7	B
13	M	Example	92.5	3.2	2.6	1.7	0.0	1,790	14	6.8	8.3	B
14	N	Example	95.4	3.1	1.5	0.0	0.0	1,698	14	5.2	6.7	A
15	O	Example	97.8	0.4	1.8	0.0	0.0	1,819	15	5.1	8.6	A
16	P	Example	95.9	1.3	1.4	1.4	0.0	1,716	8	5.9	7.4	B
17	Q	Example	91.8	3.1	1.6	3.5	0.0	1,520	9	5.3	6.8	B
18	R	Example	95.1	2.4	1.1	1.4	0.0	1,708	11	5.6	7.1	C
19	S	Example	95.4	3.2	1.1	0.3	0.0	1,860	8	6.0	7.2	B
20	T	Example	94.1	0.3	2.8	2.8	0.0	1,314	7	6.1	7.6	B
21	U	Example	93.5	2.8	1.6	2.3	0.0	1,672	5	4.0	5.5	A

(continued)

No.	Kind of steel	Classification	Structure (t/4 to 3t/4)					Tensile strength [MPa]	Prior γ grain size [μm]	Segregation (t/4 to 3t/4)		Determination of joint characteristics
			Total of martensite and tempered martensite [volume%]	Retained γ [volume%]	Ferrite [volume%]	Bainite [volume%]	Pearlite [volume%]			P content at prior γ grain boundaries [mass%]	Mn content at prior γ grain boundaries [mass%]	
22	A	Example	96.6	2.1	1.3	0.0	0.0	1,617	13	8.7	9.8	C
23	B	Example	91.2	0.9	2.4	5.5	0.0	1,759	11	4.4	5.7	A
24	C	Example	91.0	3.4	2.1	3.5	0.0	1,725	8	8.0	9.5	B
25	D	Example	97.6	2.3	0.0	0.1	0.0	1,939	9	5.9	7.4	B
26	B	Example	94.4	4.5	1.1	0.0	0.0	1,768	14	8.0	9.5	C
27	F	Example	90.2	0.7	2.4	6.7	0.0	1,870	12	4.3	5.6	A
28	G	Example	97.3	1.5	0.9	0.3	0.0	1,573	15	7.3	8.8	B
29	H	Example	92.8	4.2	0.1	2.9	0.0	1,714	13	6.7	8.2	B
30	I	Example	92.2	2.3	2.8	2.7	0.0	1,540	14	9.4	9.7	C
31	V	Comparative Example	97.0	1.6	0.0	1.4	0.0	<u>1,300</u>	10	3.9	5.7	A
32	W	Comparative Example	-									
33	X	Comparative Example	92.0	5.1	1.3	1.6	0.0	<u>1,290</u>	11	6.8	3.4	B
34	J	Comparative Example	92.3	4.3	1.7	1.7	0.0	1,795	12	<u>10.2</u>	<u>11.6</u>	D
35	K	Comparative Example	96.3	2.3	1.3	0.1	0.0	1,570	11	<u>10.6</u>	<u>10.9</u>	D
36	L	Comparative Example	93.5	2.1	1.0	3.4	0.0	1,697	8	<u>10.1</u>	<u>11.3</u>	D
37	M	Comparative Example	91.2	2.4	1.5	4.6	0.0	1,629	14	<u>11.3</u>	<u>12.7</u>	D

(continued)

No.	Kind of steel	Classification	Structure (tJ4 to 3t/4)					Tensile strength [MPa]	Prior γ grain size [μm]	Segregation (t/4 to 3t/4)		Determination of joint characteristics
			Total of martensite and tempered martensite [volume%]	Retained γ [volume%]	Ferrite [volume%]	Bainite [volume%]	Pearlite [volume%]			P content at prior γ grain boundaries [mass%]	Mn content at prior γ grain boundaries [mass%]	
38	N	Comparative Example	96.6	1.5	1.3	0.6	0.0	1,550	13	12.6	14	D
39	O	Comparative Example	90.5	3.8	0.8	4.9	0.0	1,471	8	11.1	12.5	D
40	P	Comparative Example	91.0	2.3	0.9	5.8	0.0	1,690	9	10.1	11.5	D
41	Q	Comparative Example	-									
42	R	Comparative Example	95.6	2.1	1.8	0.5	0.0	1,768	9	11.2	12.6	D
43	S	Comparative Example	97.7	0.4	1.3	0.6	0.0	1,669	12	12.4	13.8	D
44	T	Comparative Example	86.2	2.8	1.5	9.5	0.0	1,308	15	8.9	9.6	C
45	U	Comparative Example	88.2	3.1	1.8	6.9	0.0	1,305	13	9.3	9.8	C
46	A	Comparative Example	89.3	1.8	2.2	6.7	0.0	1,297	8	7.6	8.9	B
47	B	Comparative Example	94.2	2.1	2.1	1.6	0.0	1,294	9	4.0	5.8	A

[0148] As can be seen from Tables 1-1 to 3, in Example Nos. 1 to 30 of the present invention (present invention examples), the chemical composition, the metallographic structure, the Mn content and the P content (segregation degree) at the prior γ grain boundaries were within the ranges of the present invention, and as a result, a strength as high as 1,310 MPa or more and sufficient joint strength were provided.

[0149] On the other hand, in Comparative Examples Nos. 31 to 47 in which the chemical composition or the manufacturing method was outside of the range of the present invention, at least one of the chemical composition, the metallographic structure, and the Mn content and the P content (segregation degree) at the prior γ grain boundaries was outside of the range of the present invention, and any of the tensile strength and the joint strength was insufficient.

[Industrial Applicability]

[0150] According to the present invention, it is possible to provide a steel sheet which is an ultrahigh-strength steel sheet having a tensile strength of 1,310 MPa or more and can achieve sufficiently high joint strength after welding, and a welded joint. The steel sheet and the welded joint contribute to a reduction in weight of a vehicle body or the like and thus have high industrial applicability.

Claims

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

C: 0.200% or more and 0.450% or less;

Si: 0.01% or more and 2.50% or less;

Mn: 0.6% or more and 3.5% or less;

Al: 0.001% or more and 0.100% or less;

Ti: 0.001% or more and 0.100% or less;

N: 0.0100% or less;

P: 0.0400% or less;

S: 0.0100% or less;

O: 0.0060% or less;

B: 0% or more and 0.0100% or less;

Mo: 0% or more and 0.500% or less;

Nb: 0% or more and 0.200% or less;

Cr: 0% or more and 2.00% or less;

V: 0% or more and 0.500% or less;

Co: 0% or more and 0.500% or less;

Ni: 0% or more and 1.000% or less;

Cu: 0% or more and 1.000% or less;

W: 0% or more and 0.100% or less;

Ta: 0% or more and 0.100% or less;

Sn: 0% or more and 0.050% or less;

Sb: 0% or more and 0.050% or less;

As: 0% or more and 0.050% or less;

Mg: 0% or more and 0.050% or less;

Ca: 0% or more and 0.040% or less;

Y: 0% or more and 0.050% or less;

Zr: 0% or more and 0.050% or less;

La: 0% or more and 0.050% or less;

Ce: 0% or more and 0.050% or less; and

a remainder comprising Fe and impurities,

wherein a metallographic structure at a position of 1/4 to 3/4 of a sheet thickness in a sheet thickness direction from a surface contains, 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,

in the metallographic structure at the position, a P content at prior γ grain boundaries is 10.0 mass% or less, and a Mn content at the prior γ grain boundaries is 10.0 mass% or less, and

a tensile strength is 1,310 MPa or more.

2. A method for manufacturing a cold-rolled steel sheet, comprising:

a continuous casting process of obtaining a slab having the chemical composition according to claim 1 by continuous casting;

a breakdown process of reducing a thickness of the slab by performing a reduction at a reduction ratio of 30% to 60% in a temperature range of 850°C to 1,000°C;

a high-temperature heat treatment process of heating the slab after the breakdown process to 1,000°C to 1,300°C, holding the slab for 5 to 20 hours, and cooling the slab;

a hot rolling process of performing hot rolling on the slab after the high-temperature heat treatment process to obtain a hot-rolled steel sheet;

a coiling process of coiling the hot-rolled steel sheet in a temperature range of 400°C to 650°C;

a cold rolling process of pickling the hot-rolled steel sheet after the coiling process and performing cold rolling on the hot-rolled steel sheet at a reduction ratio of 20% to 80% 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 at an average temperature rising rate of 2 °C/sec or faster, holding the cold-rolled steel sheet at the annealing temperature for 60 to 300 seconds, and cooling the cold-rolled steel sheet to 250°C or lower at an average cooling rate of 10 °C/sec or faster; and

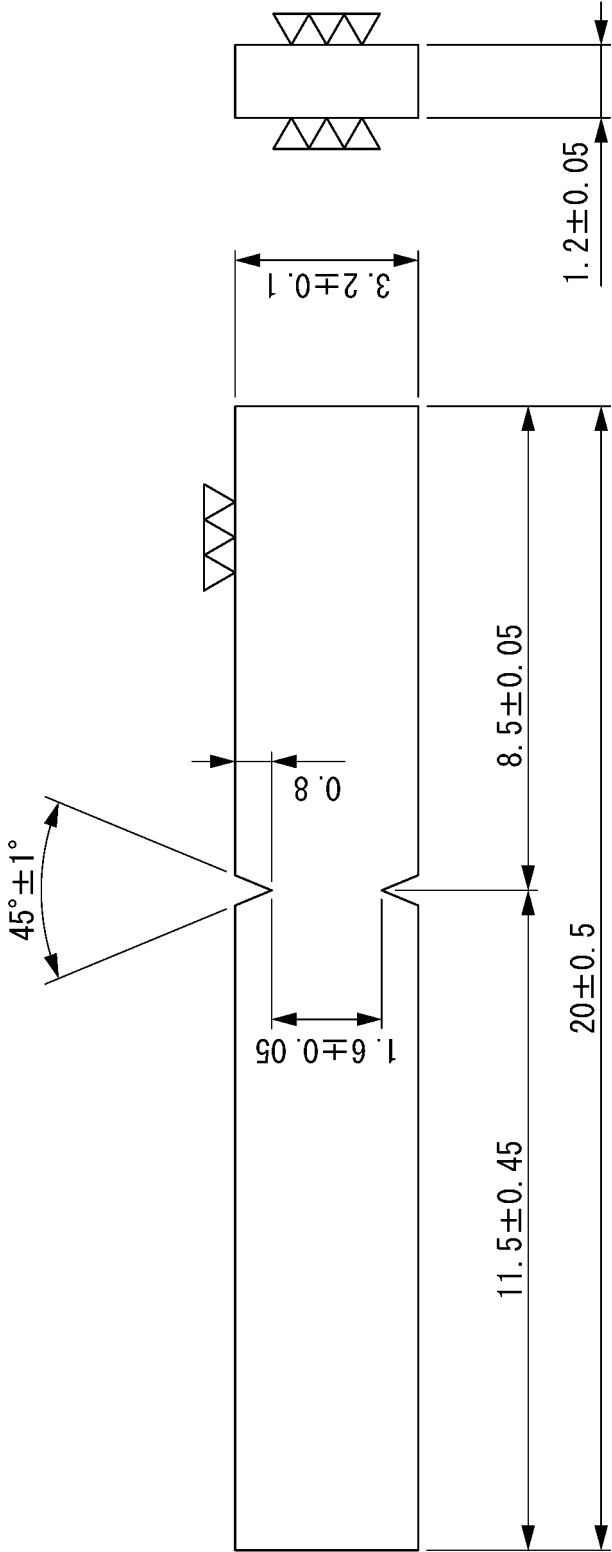
a holding process of holding the cold-rolled steel sheet after the annealing process at 150°C to 400°C for 500 seconds or shorter,

wherein, in the hot rolling process, in a case where finish rolling is performed using a rolling mill having four or more stands, an initial stand is referred to as a first stand, and a last stand is referred to as an nth stand, a sheet thickness reduction ratio in each stand from a (n-3)th stand to the nth stand is set to 30% or more, and a rolling temperature in the nth stand is set to 900°C or lower.

3. The method for manufacturing a cold-rolled steel sheet according to claim 2, wherein, in the annealing process, a coating layer containing zinc, aluminum, magnesium, or an alloy of these metals is formed on front and rear surfaces of the steel sheet.

4. A welded joint obtained by joining a plurality of steel sheets together, wherein at least one of the steel sheets is the cold-rolled steel sheet according to claim 1.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/037779

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 J

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

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.
X	WO 2020/129402 A1 (JFE STEEL CORP.) 25 June 2020 (2020-06-25) claims, paragraphs [0001], [0011]-[0097]	1, 4
A		2-3
X	WO 2020/129403 A1 (JFE STEEL CORP.) 25 June 2020 (2020-06-25) claims, paragraphs [0001], [0011]-[0097]	1, 4
A		2-3
A	JP 2010-248565 A (JFE STEEL CORP.) 04 November 2010 (2010-11-04)	1-4
A	WO 2020/209275 A1 (NIPPON STEEL CORP.) 15 October 2020 (2020-10-15)	1-4
A	WO 2020/189767 A1 (NIPPON STEEL CORP.) 24 September 2020 (2020-09-24)	1-4

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

* Special categories of cited documents:

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

12 December 2022

Date of mailing of the international search report

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Name and mailing address of the ISA/JP

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/037779

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2020/129402 A1	25 June 2020	US 2022/0056549 A1 claims, paragraphs [0001], [0018]-[0104] EP 3875615 A1 CN 113195755 A KR 10-2021-0092279 A	
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JP 2010-248565 A	04 November 2010	(Family: none)	
WO 2020/209275 A1	15 October 2020	US 2022/0186337 A1 EP 3954790 A1 KR 10-2021-0137168 A CN 113710823 A	
WO 2020/189767 A1	24 September 2020	US 2022/0119929 A1 EP 3943623 A1 KR 10-2021-0127235 A CN 113597474 A	

REFERENCES CITED IN THE DESCRIPTION

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- JP 6729835 B [0008]
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- JP 2013104081 A [0008]

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- *Analytic Chemistry*, 1986, vol. 35 [0084]