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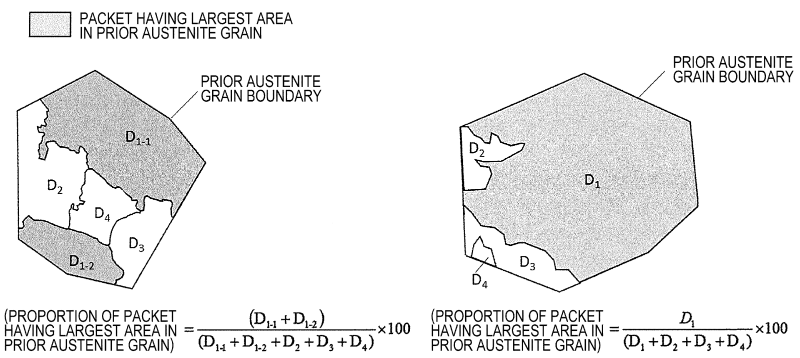
(54) **HIGH-STRENGTH STEEL SHEET AND METHOD FOR PRODUCING SAME**

(57) Objects are to provide a high strength steel sheet having 1180 MPa or higher TS and being excellent in bendability, flatness in the width direction, and working embrittlement resistance; and to provide a method for manufacturing the same.

The high strength steel sheet has a specific chemical composition and is such that in a region at 1/4 sheet thickness, the area fraction of martensite is 80% or more, the volume fraction of retained austenite is 3% or more and 15% or less, the area fraction of the total of ferrite and bainitic ferrite is 10% or less, the average grain size of prior austenite is 20 um or less, and the average of the proportions of packets having the largest area in prior austenite grains is 70% by area or less of the prior austenite grain.

FIG. 1



PACKET HAVING LARGEST AREA IN PRIOR AUSTENITE GRAIN

Processed by Luminess, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to a high strength steel sheet excellent in tensile strength, bendability, flatness in the width direction, and working embrittlement resistance, and to a method for manufacturing the same. The high strength steel sheet of the present invention may be suitably used as structural members, such as automobile parts.

Background Art

[0002] Steel sheets for automobiles are being increased in strength in order to reduce CO_2 emissions by weight reduction of vehicles and to enhance crashworthiness by weight reduction of automobile bodies at the same time, with introduction of new laws and regulations one after another. To increase the strength of automobile bodies, high strength steel sheets having a tensile strength (TS) of 1180 MPa or higher grade are increasingly applied to principal structural parts of automobiles.

[0003] High strength steel sheets used in automobiles requires excellent bendability. From the point of view of formability, steel sheets with high bendability are suitably used as, for example, bumpers and the like that have a portion bent by roll forming.

[0004] From the point of view of the performance of parts, high strength steel sheets used in automobiles require high working embrittlement resistance. For example, high strength steel sheets applied to automobile frame parts, such as bumpers, are suitably those that excel in working embrittlement resistance and are not embrittled upon being press-formed.

[0005] Furthermore, high strength steel sheets used in automobiles require high flatness. Patent Literature 1 describes that warpage of a steel sheet causes operational troubles in forming lines and adversely affects the dimensional accuracy of products. The present inventors carried out extensive studies and have found that the dimensional accuracy of products is affected not only by the warpage of steel sheets but also by the flatness in the width direction that is evaluated as steepness. For example, the steepness in the width direction is suitably 0.02 or less in order to achieve excellent dimensional accuracy.

[0006] To meet the above demands, for example, Patent Literature 2 provides a high strength steel sheet having a tensile strength of 1100 MPa or more and being excellent in YR, surface quality, and weldability, and a method for manufacturing the same. However, the technique described in Patent Literature 2 does not take into consideration flatness in the width direction or working embrittlement resistance.

[0007] Patent Literature 3 provides a hot-dip galvanized steel sheet with excellent press formability and low-temperature toughness that has a tensile strength of 980 MPa or more, and a method for manufacturing the same. While the steel sheet of Patent Literature 3 is improved in embrittlement at low temperatures, the technique does not take into consideration the working embrittlement of the steel sheet, bendability, or flatness in the width direction.

[0008] Patent Literature 4 provides a high strength steel sheet having a tensile strength of 1320 MPa or more and being excellent in workability and bendability, and a method for manufacturing the same. However, the technique described in Patent Literature 4 does not take into consideration flatness in the width direction or working embrittlement resistance.

Citation List

Patent Literature

[0009]

PTL 1: Japanese Patent No. 4947176
PTL 2: Japanese Patent No. 6525114
PTL 3: Japanese Patent No. 6777272
PTL 4: Japanese Patent No. 6338025

Non Patent Literature

[0010] NPL 1: Journal of Smart Processing, 2013, Vol. 2, No. 3, pp. 110-118

Summary of Invention

Technical Problem

[0011] The present invention has been developed in view of the circumstances discussed above. Objects of the present invention are therefore to provide a high strength steel sheet having 1180 MPa or higher TS and being excellent in bendability, flatness in the width direction, and working embrittlement resistance; and to provide a method for manufacturing the same.

Solution to Problem

[0012] The present inventors carried out extensive studies directed to solving the problems described above and have consequently found the following facts.

(1) 1180 MPa or higher TS can be realized by limiting the area fraction of martensite to 80% or more and the area fraction of the total of ferrite and bainitic ferrite to 10% or less.
(2) Excellent bendability can be realized by limiting the volume fraction of retained austenite to 3% or more.
(3) Excellent flatness in the width direction can be achieved by limiting the proportion of a packet having the largest area in a prior austenite grain to 70% by area or less on average.
(4) Excellent working embrittlement resistance can be realized by limiting the volume fraction of retained austenite to 15% or less, the proportion of a packet having the largest area in a prior austenite grain to 70% by area or less on average, and the average prior austenite grain size to 20 um or less.

[0013] The present invention has been made based on the above findings. Specifically, a summary of configurations of the present invention is as follows.

[1] A high strength steel sheet having a chemical composition including, in mass%, C: 0.030% or more and 0.500% or less, Si: 0.50% or more and 2.50% or less, Mn: 1.50% or more and 5.00% or less, P: 0.100% or less, S: 0.0200% or less, Al: 1.000% or less, N: 0.0100% or less, and O: 0.0100% or less, a balance being Fe and incidental impurities, the high strength steel sheet being such that in a region at 1/4 sheet thickness, an area fraction of martensite is 80% or more, a volume fraction of retained austenite is 3% or more and 15% or less, an area fraction of a total of ferrite and bainitic ferrite is 10% or less, an average grain size of prior austenite is 20 um or less, and an average of proportions of packets having the largest area in prior austenite grains is 70% by area or less of the prior austenite grain.
[2] The high strength steel sheet according to [1], wherein the chemical composition further includes at least one element selected from, in mass%, Ti: 0.200% or less, Nb: 0.200% or less, V: 0.200% or less, Ta: 0.10% or less, W: 0.10% or less, B: 0.0100% or less, Cr: 1.00% or less, Mo: 1.00% or less, Co: 0.010% or less, Ni: 1.00% or less, Cu: 1.00% or less, Sn: 0.200% or less, Sb: 0.200% or less, Ca: 0.0100% or less, Mg: 0.0100% or less, REM: 0.0100% or less, Zr: 0.100% or less, Te: 0.100% or less, Hf: 0.10% or less, and Bi: 0.200% or less.
[3] The high strength steel sheet according to [1] or [2], which has a coated layer on a surface of the steel sheet.
[4] A method for manufacturing the high strength steel sheet according to [1] or [2], the method including providing a cold rolled steel sheet produced by subjecting a steel having the chemical composition to hot rolling, pickling, and cold rolling; annealing the steel sheet by heating at an annealing temperature of 750°C or above and 950°C or below for a holding time at the annealing temperature of 10 seconds or more and 1000 seconds or less; bending and unbending the steel sheet 1 to 15 times in total with a roll having a radius of 800 mm or less during the annealing; cooling the steel sheet at an average cooling rate of 20°C/s or more in a temperature range from 700°C to 600°C and at an average cooling rate of 20°C/s or more in a temperature range from 499°C to Ms; bending and unbending the steel sheet in the temperature range from 499°C to Ms, 1 to 15 times in total with a roll having a radius of 800 mm or less; cooling the steel sheet at an average cooling rate of 150°C/s or less in a temperature range from Ms to a cooling stop temperature Ta; applying a tension to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta while controlling the tension to 5 MPa or more and 100 MPa or less, the cooling stop temperature Ta being 100°C or above and (Ms - 80°C) or below where Ms is martensite start temperature (°C) defined by formula (1); and tempering the steel sheet at a tempering temperature of Ta or above and 450°C or below for a holding time at the tempering temperature of 10 seconds or more and 1000 seconds or less,

$$Ms = 519 - 474 \times [\% C] - 30.4 \times [\% Mn] - 12.1 \times [\% Cr] - 7.5 \times [\% Mo] - 17.7 \times [\% Ni] \quad (1)$$

wherein [% C], [% Mn], [% Cr], [% Mo], and [% Ni] indicate the contents (mass%) of C, Mn, Cr, Mo, and Ni, respectively, and are zero when the element is absent.

[5] The method for manufacturing the high strength steel sheet according to [4], further including performing a coating treatment.

Advantageous Effects of Invention

[0014] According to the present invention, a high strength steel sheet can be obtained that has 1180 MPa or higher TS and excels in bendability, flatness in the width direction, and working embrittlement resistance. Furthermore, for example, the high strength steel sheet of the present invention may be applied to automobile structural members to reduce the weight of automobile bodies and thereby to enhance fuel efficiency. Thus, the present invention is highly valuable in industry.

Brief Description of Drawings

[0015]

[Fig. 1] Fig. 1 is a set of views illustrating a structure of a packet having the largest area in a prior austenite grain according to the present invention, and how the proportion of the packet is calculated.
[Fig. 2] Fig. 2 is a set of views illustrating the concept of the steepness λ in the width direction of a steel sheet according to the present invention, and how the steepness is calculated.

Description of Embodiments

[0016] Embodiments of the present invention will be described below.
[0017] First, appropriate ranges of the chemical composition of the high strength steel sheet and the reasons why the chemical composition is thus limited will be described. In the following description, "%" indicating the contents of constituent elements of steel means "mass%" unless otherwise specified.

[C: 0.030% or more and 0.500% or less]

[0018] Carbon is one of the important basic components of steel. Particularly in the present invention, carbon is an important element that affects the amount of martensite and the total amount of ferrite and bainitic ferrite. When the C content is less than 0.030%, the amount of martensite is lowered and the total amount of ferrite and bainitic ferrite is increased, with the result that realizing 1180 MPa or higher TS is difficult. When, on the other hand, the C content is more than 0.500%, martensite becomes brittle to cause deterioration in working embrittlement resistance. Thus, the C content is limited to 0.030% or more and 0.500% or less. The lower limit of the C content is preferably 0.050% or more. The upper limit of the C content is preferably 0.400% or less. The lower limit of the C content is more preferably 0.100% or more. The upper limit of the C content is more preferably 0.350% or less.

[Si: 0.50% or more and 2.50% or less]

[0019] Silicon is one of the important basic components of steel and is an important element that affects TS and the amount of retained austenite. When the Si content is less than 0.50%, the strength of martensite decreases to make it difficult to achieve 1180 MPa or higher TS. When, on the other hand, the Si content is more than 2.50%, the amount of retained austenite is increased excessively to cause deterioration in working embrittlement resistance. Thus, the Si content is limited to 0.50% or more and 2.50% or less. The lower limit of the Si content is preferably 0.55% or more. The upper limit of the Si content is preferably 2.00% or less. The lower limit of the Si content is more preferably 0.60% or more. The upper limit of the Si content is more preferably 1.80% or less.

[Mn: 1.50% or more and 5.00% or less]

[0020] Manganese is one of the important basic components of steel and is an important element that affects the amount of martensite and the total amount of ferrite and bainitic ferrite. When the Mn content is less than 1.50%, the amount of martensite is lowered and the total amount of ferrite and bainitic ferrite is increased, with the result that realizing 1180 MPa or higher TS is difficult. When, on the other hand, the Mn content is more than 5.00%, martensite becomes brittle to cause deterioration in working embrittlement resistance. Thus, the Mn content is limited to 1.50% or more and 5.00% or less. The lower limit of the Mn content is preferably 2.00% or more. The upper limit of the Mn content is preferably 4.50% or less. The lower limit of the Mn content is more preferably 2.20% or more. The upper limit of the Mn content is more preferably 4.00% or less.

[P: 0.100% or less]

[0021] Phosphorus is segregated at prior austenite grain boundaries and makes the grain boundaries brittle, thereby lowering the ultimate deformability of steel sheets and causing deterioration in working embrittlement resistance. Thus, the P content needs to be 0.100% or less. The lower limit of the P content is not particularly specified. In view of the fact that phosphorus is a solid solution strengthening element and can increase the strength of steel sheets, the lower limit is preferably 0.001% or more. For the reasons above, the P content is limited to 0.100% or less. The lower limit of the P content is preferably 0.001% or more. The upper limit of the P content is preferably 0.070% or less.

[S: 0.0200% or less]

[0022] Sulfur forms sulfides and lowers the ultimate deformability of steel sheets to cause deterioration in working embrittlement resistance. Thus, the S content needs to be 0.0200% or less. The lower limit of the S content is not particularly specified but is preferably 0.0001% or more due to production technique limitations. For the reasons above, the S content is limited to 0.0200% or less. The lower limit of the S content is preferably 0.0001% or more. The upper limit of the S content is preferably 0.0050% or less.

[Al: 1.000% or less]

[0023] Aluminum forms the oxide and lowers the ultimate deformability of steel sheets to cause deterioration in working embrittlement resistance. Thus, the Al content needs to be 1.000% or less. The lower limit of the Al content is not particularly specified. In view of the fact that aluminum suppresses the occurrence of carbides during continuous annealing and promotes the formation of retained austenite, the Al content is preferably 0.001% or more. For the reasons above, the Al content is limited to 1.000% or less. The lower limit of the Al content is preferably 0.001% or more. The upper limit of the Al content is preferably 0.500% or less.

[N: 0.0100% or less]

[0024] Nitrogen forms nitrides and lowers the ultimate deformability of steel sheets to cause deterioration in working embrittlement resistance. Thus, the N content needs to be 0.0100% or less. The lower limit of the N content is not particularly specified, but the N content is preferably 0.0001% or more due to production technique limitations. For the reasons above, the N content is limited to 0.0100% or less. The lower limit of the N content is preferably 0.0001% or more. The upper limit of the N content is preferably 0.0050% or less.

[O: 0.0100% or less]

[0025] Oxygen forms oxides and lowers the ultimate deformability of steel sheets to cause deterioration in working embrittlement resistance. Thus, the O content needs to be 0.0100% or less. The lower limit of the O content is not particularly specified but the O content is preferably 0.0001% or more due to production technique limitations. For the reasons above, the O content is limited to 0.0100% or less. The lower limit of the O content is preferably 0.0001% or more. The upper limit of the O content is preferably 0.0050% or less.

[0026] The chemical composition of the high strength steel sheet according to an embodiment of the present invention includes the components described above, and the balance is Fe and incidental impurities. Here, the incidental impurities include Zn, Pb, As, Ge, Sr, and Cs. A total of 0.100% or less of these impurities is acceptable.

[0027] In addition to the components in the proportions described above, the high strength steel sheet of the present invention may further include at least one element selected from, in mass%, Ti: 0.200% or less, Nb: 0.200% or less, V: 0.200% or less, Ta: 0.10% or less, W: 0.10% or less, B: 0.0100% or less, Cr: 1.00% or less, Mo: 1.00% or less, Ni: 1.00% or less, Co: 0.010% or less, Cu: 1.00% or less, Sn: 0.200% or less, Sb: 0.200% or less, Ca: 0.0100% or less, Mg: 0.0100% or less, REM: 0.0100% or less, Zr: 0.100% or less, Te: 0.100% or less, Hf: 0.10% or less, and Bi: 0.200% or less. These elements may be contained singly or in combination.

[0028] When the contents of Ti, Nb, and V are each 0.200% or less, coarse precipitates and inclusions will not occur in large amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the contents of Ti, Nb, and V are each preferably 0.200% or less. The lower limits of the contents of Ti, Nb, and V are not particularly specified. These elements form fine carbides, nitrides, or carbonitrides during hot rolling or continuous annealing to increase the strength of steel sheets. In view of this fact, the contents of Ti, Nb, and V are each more preferably 0.001% or more. When titanium, niobium, and vanadium are added, the contents thereof are each limited to 0.200% or less for the reasons above. The lower limits of the contents of Ti, Nb, and V, when added, are each more preferably 0.001% or more. The upper limits of the contents of Ti, Nb, and V, when added, are each more preferably 0.100% or less.

[0029] When the contents of Ta and W are each 0.10% or less, coarse precipitates and inclusions will not occur in large amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the contents of Ta and W are each preferably 0.10% or less. The lower limits of the contents of Ta and W are not particularly specified. These elements form fine carbides, nitrides, or carbonitrides during hot rolling or continuous annealing to increase the strength of steel sheets. In view of this fact, the contents of Ta and W are each more preferably 0.01% or more. When tantalum and tungsten are added, the contents thereof are each limited to 0.10% or less for the reasons above. The lower limits of the contents of Ta and W, when added, are each more preferably 0.01% or more. The upper limits of the contents of Ta and W, when added, are each more preferably 0.08% or less.

[0030] When the B content is 0.0100% or less, inner cracks that lower the ultimate deformability of steel sheets will not form during casting or hot rolling and thus there will be no deterioration in working embrittlement resistance. Thus, the B content is preferably 0.0100% or less. The lower limit of the B content is not particularly specified. The B content is more preferably 0.0003% or more in view of the fact that this element is segregated at austenite grain boundaries during annealing and enhances hardenability. When boron is added, the content thereof is limited to 0.0100% or less for the reasons above. The lower limit of the content of B, when added, is more preferably 0.0003% or more. The upper limit of the content of B, when added, is more preferably 0.0080% or less.

[0031] When the contents of Cr, Mo, and Ni are each 1.00% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the contents of Cr, Mo, and Ni are each preferably 1.00% or less. The lower limits of the contents of Cr, Mo, and Ni are not particularly specified. In view of the fact that these elements enhance hardenability, the contents of Cr, Mo, and Ni are each more preferably 0.01% or more. When chromium, molybdenum, and nickel are added, the contents thereof are each limited to 1.00% or less for the reasons above. The lower limits of the contents of Cr, Mo, and Ni, when added, are each more preferably 0.01% or more. The upper limits of the contents of Cr, Mo, and Ni, when added, are each more preferably 0.80% or less.

[0032] When the Co content is 0.010% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the Co content is preferably 0.010% or less. The lower limit of the Co content is not particularly specified. In view of the fact that this element enhances hardenability, the Co content is more preferably 0.001% or more. When cobalt is added, the content thereof is limited to 0.010% or less for the reasons above. The lower limit of the content of Co, when added, is more preferably 0.001% or more. The upper limit of the content of Co, when added, is more preferably 0.008% or less.

[0033] When the Cu content is 1.00% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the Cu content is preferably 1.00% or less. The lower limit of the Cu content is not particularly specified. In view of the fact that this element enhances hardenability, the Cu content is preferably 0.01% or more. When copper is added, the content thereof is limited to 1.00% or less for the reasons above. The lower limit of the content of Cu, when added, is more preferably 0.01% or more. The upper limit of the content of Cu, when added, is more preferably 0.80% or less.

[0034] When the Sn content is 0.200% or less, inner cracks that lower the ultimate deformability of steel sheets will not form during casting or hot rolling and thus there will be no deterioration in working embrittlement resistance. Thus, the Sn content is preferably 0.200% or less. The lower limit of the Sn content is not particularly specified. The Sn content is more preferably 0.001% or more in view of the fact that tin enhances hardenability (in general, is an element that enhances corrosion resistance). When tin is added, the content thereof is limited to 0.200% or less for the reasons above. The lower limit of the content of Sn, when added, is more preferably 0.001% or more. The upper limit of the content of Sn, when added, is more preferably 0.100% or less.

[0035] When the Sb content is 0.200% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the Sb content is preferably 0.200% or less. The lower limit of the Sb content is not particularly specified. In view of the fact that this element enables control of the thickness of surface layer softening and the strength, the Sb content is more preferably 0.001% or more. When antimony is added, the content thereof is limited to 0.200% or less for the reasons above. The lower limit of the content of Sb, when added, is more preferably 0.001% or more. The upper limit of the content of Sb, when added, is more preferably 0.100% or less.

[0036] When the contents of Ca, Mg, and REM are each 0.0100% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the contents of Ca, Mg, and REM are each preferably 0.0100% or less. The lower limits of the contents of Ca, Mg, and REM are not particularly specified. In view of the fact that these elements change the shapes of nitrides and sulfides into spheroidal and enhance the ultimate deformability of steel sheets, the contents of Ca, Mg, and REM are each more preferably 0.0005% or more. When calcium, magnesium, and rare earth metal(s) are added, the contents thereof are each limited to 0.0100% or less for the reasons above. The lower limits of the contents of Ca, Mg, and REM, when added, are each more preferably 0.0005% or more. The upper limits of the contents of Ca, Mg, and REM, when added, are each more preferably 0.0050% or less.

[0037] When the contents of Zr and Te are each 0.100% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the contents of Zr and Te are each preferably 0.100% or less. The lower limits of the contents of Zr and Te are not particularly specified. In view of the fact that these elements change the shapes of nitrides and sulfides into spheroidal and enhance the ultimate deformability of steel sheets, the contents of Zr and Te are each more preferably 0.001% or more. When zirconium and tellurium are added, the contents thereof are each limited to 0.100% or less for the reasons above. The lower limits of the contents of Zr and Te, when added, are each more preferably 0.001% or more. The upper limits of the contents of Zr and Te, when added, are each more preferably 0.080% or less.

[0038] When the Hf content is 0.10% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the Hf content is preferably 0.10% or less. The lower limit of the Hf content is not particularly specified. In view of the fact that this element changes the shapes of nitrides and sulfides into spheroidal and enhances the ultimate deformability of steel sheets, the Hf content is more preferably 0.01% or more. When hafnium is added, the content thereof is limited to 0.10% or less for the reasons above. The lower limit of the content of Hf, when added, is more preferably 0.01% or more. The upper limit of the content of Hf, when added, is more preferably 0.08% or less.

[0039] When the Bi content is 0.200% or less, coarse precipitates and inclusions will not occur in increased amounts and thus will not cause lowering of the ultimate deformability of steel sheets; hence there will be no deterioration in working embrittlement resistance. Thus, the Bi content is preferably 0.200% or less. The lower limit of the Bi content is not particularly specified. In view of the fact that this element reduces the occurrence of segregation, the Bi content is more preferably 0.001% or more. When bismuth is added, the content thereof is limited to 0.200% or less for the reasons above. The lower limit of the content of Bi, when added, is more preferably 0.001% or more. The upper limit of the content of Bi, when added, is more preferably 0.100% or less.

[0040] When the content of any of Ti, Nb, V, Ta, W, B, Cr, Mo, Ni, Co, Cu, Sn, Sb, Ca, Mg, REM, Zr, Te, Hf, and Bi is below the preferred lower limit, the element does not impair the advantageous effects of the present invention and is regarded as an incidental impurity.

[0041] Next, the steel microstructure of the high strength steel sheet of the present invention will be described.

[Area fraction of martensite: 80% or more]

[0042] This configuration is a very important requirement that constitutes the present invention. 1180 MPa or higher TS can be achieved when the area fraction of martensite is 80% or more. Thus, the area fraction of martensite is limited to 80% or more. The area fraction is preferably 82% or more, and more preferably 84% or more.

[Volume fraction of retained austenite: 3% or more and 15% or less]

[0043] This configuration is a very important requirement that constitutes the present invention. When the volume fraction of retained austenite is less than 3%, it is difficult to realize excellent bendability because the anti-cracking effect of retained austenite cannot be obtained at the time of bending. When the amount of retained austenite is more than 15%, retained austenite is excessively transformed into hard martensite at the time of working and the steel sheet is lowered in ultimate deformability and will not attain excellent working embrittlement resistance. Thus, the amount of retained austenite is limited to 3% or more and 15% or less. The lower limit of the amount of retained austenite is preferably 5% or more. The upper limit of the amount of retained austenite is preferably 140 or less. The lower limit of the amount of retained austenite is more preferably 7% or more. The upper limit of the amount of retained austenite is more preferably 13% or less.

[0044] Here, retained austenite is measured as follows. The steel sheet is polished to expose a face 0.1 mm below 1/4 sheet thickness and is thereafter further chemically polished to expose a face 0.1 mm below the face exposed above. The face is analyzed with an X-ray diffractometer using CoKα radiation to determine the integral intensity ratios of the diffraction peaks of {200}, {220}, and {311} planes of fcc iron and {200}, {211}, and {220} planes of bcc iron. Nine integral intensity ratios thus obtained are averaged to determine retained austenite.

[Area fraction of the total of ferrite and bainitic ferrite: 10% or less]

[0045] This configuration is a very important requirement that constitutes the present invention. When the total amount of ferrite and bainitic ferrite is more than 10%, it is difficult to achieve 1180 MPa or higher TS. Thus, the total amount of ferrite and bainitic ferrite is limited to 10% or less. The total amount is preferably 8% or less, and more preferably 5% or less. The lower limit of the total amount of ferrite and bainitic ferrite is not particularly limited. The total amount may be 0%.

[0046] Here, the total amount of ferrite and bainitic ferrite is measured as follows. A longitudinal cross section of the steel sheet is polished and is etched with 3 vol% Nital. A portion at 1/4 sheet thickness (a location corresponding to 1/4 of the sheet thickness in the depth direction from the steel sheet surface) is observed using SEM in 10 fields of view at a magnification of ×2000. In the microstructure images, ferrite and bainitic ferrite are recessed structures having a flat interior and containing no inner carbides. The values thus obtained are averaged to determine the total amount of ferrite and bainitic ferrite.

[0047] The amount of martensite is measured as follows. The amount of martensite can be determined by measuring the amounts of retained austenite, ferrite, and bainitic ferrite based on the methods described above, and subtracting the total thereof from 100%. Thus, the amount of martensite in the present invention includes both quenched martensite and tempered martensite. Because the volume fraction of retained austenite is almost equal to the area fraction, the amount is subtracted as such from 100% together with the amounts of ferrite and bainitic ferrite expressed in area fraction.

[Average grain size of prior austenite: 20 um or less]

[0048] This configuration is a very important requirement that constitutes the present invention. Reducing the average grain size of prior austenite can suppress crack propagation and thereby enhances the working embrittlement resistance of steel sheets. In order to obtain these effects, the average grain size of prior austenite needs to be 20 um or less. The lower limit of the average grain size of prior austenite is not particularly specified but is preferably 2 um or more due to production technique limitations. For the reasons above, the average grain size of prior austenite is limited to 20 um or less. The average grain size is preferably 2 um or more. The average grain size is preferably 15 um or less. The average grain size is more preferably 3 um or more. The average grain size is more preferably 10 um or less.

[0049] Here, the average grain size of prior austenite is measured as follows. A longitudinal cross section of the steel sheet is polished and is etched with, for example, a mixed solution of picric acid and ferric chloride to expose prior austenite grain boundaries. Portions at 1/4 sheet thickness (locations corresponding to 1/4 of the sheet thickness in the depth direction from the steel sheet surface) are photographed with an optical microscope each in 3 to 10 fields of view at a magnification of ×400. Twenty straight lines including 10 vertical lines and 10 horizontal lines are drawn at regular intervals on the image data obtained, and the grain size is determined by a linear intercept method.

[Average of the proportions of packets having the largest area in prior austenite grains: 70% by area or less]

[0050] This configuration is a very important requirement that constitutes the present invention. The proportion of a packet having the largest area in a prior austenite grain affects the flatness in the width direction and the working embrittlement resistance. As illustrated in Fig. 1, a prior austenite grain contains up to four kinds of packets distinguished by crystal habit plane formed by transformation. The packet having the largest area in a prior austenite grain is the packet that occupies the largest area among such packets.

[0051] The proportion of one packet in a prior austenite grain is determined by dividing the area of the packet of interest by the area of the whole prior austenite grain.

[0052] As a result of extensive studies, the present inventors have found that strain among the packets is reduced and the flatness in the width direction is improved by lowering the proportion of a packet having the largest area in a prior austenite grain. The present inventors have also found that lowering the proportion of a packet having the largest area in a prior austenite grain leads to a fine microstructure and suppresses crack propagation, thereby enhancing the working embrittlement resistance of the steel sheet. Thus, the average of the proportions of packets having the largest area in prior austenite grains is limited to 70% or less. The average proportion is preferably 60% or less. The lower limit of the average proportion of packets having the largest area in prior austenite grains is not particularly limited. The grains contain up to four kinds of packets. When four packets are evenly distributed, the proportion of a packet having the largest area in the prior austenite grain is 25%. Thus, the lower limit of the average proportion of packets having the largest area in prior austenite grains is preferably 25% or more. However, the lower limit of the average proportion is not necessarily limited thereto.

[0053] Here, the average proportion of packets having the largest area in prior austenite grains is measured as follows. First, a test specimen for microstructure observation is sampled from the cold rolled steel sheet. Next, the sampled test specimen is polished by vibration polishing with colloidal silica to expose a cross section in the rolling direction (a longitudinal cross section) for use as observation surface. The observation surface is specular. Next, electron backscatter diffraction (EBSD) measurement is performed with respect to a portion at 1/4 sheet thickness (a location corresponding to 1/4 of the sheet thickness in the depth direction from the steel sheet surface) to obtain local crystal orientation data. Here, the SEM magnification is ×1000, the step size is 0.2 um, the measured region is 80 um square, and the WD is 15 mm. The local orientation data obtained is analyzed with OIM Analysis 7 (OIM), and a map (a CP map) that shows close-packed plane groups (CP groups) with different colors is created using the method described in Non Patent Literature 1. In the present invention, a packet is defined as a region or regions belonging to the same CP group. From the CP map obtained, the area of the packet having the largest area is determined and is divided by the area of the whole prior austenite grain to give the proportion of the packet having the largest area in the prior austenite grain. This analysis is performed with respect to 10 or more adjacent prior austenite grains, and the results are averaged to give the average proportion of packets having the largest area in prior austenite grains.

[0054] Next, a manufacturing method of the present invention will be described.

[0055] In the present invention, a steel material (a steel slab) may be obtained by any known steelmaking method without limitation, such as a converter or an electric arc furnace. To prevent macro-segregation, the steel slab (the slab) is preferably produced by a continuous casting method.

[0056] In the present invention, the slab heating temperature, the slab soaking holding time, and the coiling temperature in hot rolling are not particularly limited. For example, the steel slab may be hot rolled in such a manner that the slab is heated and is then rolled, that the slab is subjected to hot direct rolling after continuous casting without being heated, or that the slab is subjected to a short heat treatment after continuous casting and is then rolled. The slab heating temperature, the slab soaking holding time, the finish rolling temperature, and the coiling temperature in hot rolling are not particularly limited. The lower limit of the slab heating temperature is preferably 1100°C or above. The upper limit of the slab heating temperature is preferably 1300°C or below. The lower limit of the slab soaking holding time is preferably 30 minutes or more. The upper limit of the slab soaking holding time is preferably 250 minutes or less. The lower limit of the finish rolling temperature is preferably Ar_3 transformation temperature or above. Furthermore, the lower limit of the coiling temperature is preferably 350°C or above. The upper limit of the coiling temperature is preferably 650°C or below.

[0057] The hot rolled steel sheet thus produced is pickled. Pickling can remove oxides on the steel sheet surface and is thus important to ensure good chemical convertibility and a high quality of coating in the final high strength steel sheet. Pickling may be performed at a time or several. The hot rolled sheet that has been pickled may be cold rolled directly or may be subjected to heat treatment before cold rolling.

[0058] The rolling reduction in cold rolling and the sheet thickness after rolling are not particularly limited. The lower limit of the rolling reduction is preferably 30% or more. The upper limit of the rolling reduction is preferably 80% or less. The advantageous effects of the present invention may be obtained without any limitations on the number of rolling passes and the rolling reduction in each pass.

[0059] The cold rolled steel sheet obtained as described above is annealed. Annealing conditions are as follows.

[Annealing temperature: 750°C or above and 950°C or below]

[0060] When the annealing temperature is below 750°C, the amount of martensite is lowered and the total amount of ferrite and bainitic ferrite is increased, with the result that realizing 1180 MPa or higher TS is difficult. When, on the other hand, the annealing temperature is above 950°C, prior austenite grains are excessively increased in size and the prior austenite grain size exceeds 20 um to give rise to a decrease in working embrittlement resistance. Thus, the annealing temperature is limited to 750°C or above and 950°C or below. The lower limit of the annealing temperature is preferably 800°C or above. The upper limit of the annealing temperature is preferably 900°C or below.

[Holding time during annealing at the annealing temperature: 10 seconds or more and 1000 seconds or less]

[0061] When the holding time at the annealing temperature is less than 10 seconds, the amount of martensite is lowered and the total amount of ferrite and bainitic ferrite is increased, with the result that realizing 1180 MPa or higher TS is difficult. When, on the other hand, the holding time at the annealing temperature is more than 1000 seconds, prior austenite grains are excessively increased in size to cause a decrease in working embrittlement resistance. Thus, the holding time at the annealing temperature is limited to 10 seconds or more and 1000 seconds or less. The lower limit of the holding time at the annealing temperature is preferably 50 seconds or more. The upper limit of the holding time at the annealing temperature is preferably 500 seconds or less.

[During the annealing, the steel sheet is bent and unbent 1 to 15 times in total with a roll having a radius of 800 mm or less.]

[0062] As a result of extensive studies, the present inventors have found that bending and unbending of the steel sheet during annealing affects the proportion of a packet having the largest area in a prior austenite grain. When the steel sheet being annealed is not subjected to bending and unbending with a roll having a radius of 800 mm or less, the amount of nucleation sites for martensite transformation is reduced. Consequently, the average proportion of packets having the largest area in prior austenite grains exceeds 70%, and the flatness in the width direction and also the working embrittlement resistance are deteriorated. When, on the other hand, the steel sheet being annealed is subjected to bending and unbending 16 times or more with a roll having a radius of 800 mm or less, the steel sheet is deteriorated in ultimate deformability and also in working embrittlement resistance. Thus, in the annealing, the total count of bending and unbending with a roll having a radius of 800 mm or less is limited to 1 or more and 15 or less. The radius of the roll is preferably 600 mm or less. The lower limit of the total count of bending and unbending is preferably 3 or more. The upper limit of the total count of bending and unbending is preferably 10 or less. The lower limit of the radius of the roll is not necessarily limited but is preferably 50 mm or more.

[0063] Incidentally, "bending and unbending" is a treatment that bends the steel sheet with a roll in one direction according to a known technique and unbends the steel sheet in the opposite direction to cancel the bend. Bending and unbending are not counted in pairs. That is, each bending is counted one and each unbending is counted one.

[Average cooling rate in the temperature range from 700°C to 600°C: 20°C/s or more]

[0064] As a result of extensive studies, the present inventors have found that the average cooling rate in the temperature range from 700°C to 600°C affects the proportion of a packet having the largest area in a prior austenite grain. When the average cooling rate in the temperature range from 700°C to 600°C is less than 20°C/s, the effects imparted by bending and unbending of the steel sheet during annealing are lowered and the amount of nucleation sites for martensite transformation is reduced. Consequently, the average proportion of packets having the largest area in prior austenite grains exceeds 70%, and the flatness in the width direction and also the working embrittlement resistance are deteriorated. Thus, the average cooling rate from 750°C to 600°C is limited to 20°C/s or more and is preferably 30°C/s or more. The upper limit is not necessarily limited but is preferably 100°C/s or less.

[Average cooling rate in the temperature range from 499°C to Ms: 20°C/s or more]

[0065] The average cooling rate in the temperature range from 499°C to Ms affects the total area fraction of ferrite and bainitic ferrite. When the average cooling rate in the temperature range from 499°C to Ms is less than 20°C/s, the total amount of ferrite and bainitic ferrite is increased to make it difficult to realize 1180 MPa or higher TS. Thus, the average cooling rate in the temperature range from 499°C to Ms is limited to 20°C/s or more. The average cooling rate is preferably 25°C/s or more. The upper limit is not necessarily limited but is preferably 100°C/s or less.

[0066] The martensite start temperature Ms (°C) is defined by the following formula (1):

$$Ms = 519 - 474 \times [\% C] - 30.4 \times [\% Mn] - 12.1 \times [\% Cr] - 7.5 \times [\% Mo] - 17.7 \times [\% Ni] \quad (1)$$

wherein [% C], [% Mn], [% Cr], [% Mo], and [% Ni] indicate the contents (mass%) of C, Mn, Cr, Mo, and Ni, respectively, and are zero when the element is absent.

[0067] [The steel sheet in the temperature range from 499°C to Ms is bent and unbent 1 to 15 times in total with a roll having a radius of 800 mm or less.]

[0068] As a result of extensive studies, the present inventors have found that bending and unbending of the steel sheet in the temperature range from 499°C to Ms affects the proportion of a packet having the largest area in a prior austenite grain. When the steel sheet in the temperature ranges from 499°C to Ms is not subjected to bending and unbending with a roll having a radius of 800 mm or less, the amount of martensite nucleation sites is reduced. Consequently, the average proportion of packets having the largest area in prior austenite grains exceeds 70%, and the flatness in the width direction and also the working embrittlement resistance are deteriorated. When, on the other hand, the steel sheet in the temperature ranges from 499°C to Ms is subjected to bending and unbending 16 times or more with a roll having a radius of 800 mm or less, the steel sheet is deteriorated in ultimate deformability and also in working embrittlement resistance. Thus, the total count of bending and unbending in the temperature range from 499°C to Ms with a roll having a radius of 800 mm or less is limited to 1 or more and 15 or less. The radius of the roll is preferably 600 mm or less. The lower limit of the total count of bending and unbending is preferably 3 or more. The lower limit of the total count of bending and unbending is preferably 10 or less. The lower limit of the radius of the roll is not necessarily limited but is preferably 50 mm or more.

[Average cooling rate in the temperature range from Ms to cooling stop temperature Ta: 150°C/s or less]

[0069] As a result of extensive studies, the present inventors have found that the average cooling rate in the temperature range from Ms to the cooling stop temperature Ta affects the proportion of a packet having the largest area in a prior austenite grain. When the average cooling rate in the temperature range from Ms to the cooling stop temperature Ta is more than 150°C/s, the martensite transformation rate is so fast that a packet grows fast easily. Consequently, the average proportion of packets having the largest area in prior austenite grains exceeds 70%, and the flatness in the width direction and also the working embrittlement resistance are deteriorated. Thus, the average cooling rate in the temperature range from Ms to the cooling stop temperature Ta is limited to 150°C/s or less. The average cooling rate is preferably 120°C/s or less. The lower limit is not necessarily limited but is preferably 5°C/s or more.

[Tension applied to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta: 5 MPa or more and 100 MPa or less]

[0070] As a result of extensive studies, the present inventors have found that the application of tension to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta affects the proportion of a packet having the largest area in a prior austenite grain. When the tension applied to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta is less than 5 MPa, the amount of martensite nucleation sites is reduced. Consequently, the average proportion of packets having the largest area in prior austenite grains exceeds 70%, and the flatness in the width direction and also the working embrittlement resistance are deteriorated. When, on the other hand, more than 100 MPa tension is applied to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta, the ultimate deformability of the steel sheet is lowered and the working embrittlement resistance is deteriorated. Thus, the tension applied to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta is limited to 5 MPa or more and 100 MPa or less. The lower limit of the tension applied to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta is preferably 6 MPa or more. The upper limit of the tension applied to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta is preferably 50 MPa or less. The tension is applied in a usual manner. As an example, the tension may be applied by controlling the roll speeds of the rolls in the furnace.

[0071] While the bending and unbending process increases the number of nucleation sites that are martensite start sites, the tension application process produces different effects by promoting martensite transformation itself.

[Cooling stop temperature Ta: 100°C or above and (Ms - 80°C) or below]

[0072] When the cooling stop temperature Ta is below 100°C, the amount of retained austenite decreases and bendability is lowered. When, on the other hand, the cooling stop temperature Ta is above (Ms - 80°C), the amount of retained austenite is excessively increased and the prior austenite grain size is excessively enlarged to cause deterioration in working embrittlement resistance. Thus, the cooling stop temperature Ta is limited to 100°C or above and (Ms - 80°C) or below. The lower limit of the cooling stop temperature Ta is preferably 120°C or above. The upper limit of the cooling stop temperature Ta is preferably (Ms - 100°C) or below.

[Tempering temperature: Ta or above and 450°C or below]

[0073] After the cooling is stopped at the cooling stop temperature Ta, the steel sheet is held at the temperature or is reheated and held at a temperature of 450°C or below to stabilize retained austenite. When the tempering temperature is below Ta, retained austenite cannot be obtained as desired and consequently bendability is lowered. When the tempering temperature is above 450°C, martensite is excessively tempered to make it difficult to achieve 1180 MPa or higher TS. Thus, the tempering temperature is limited to Ta or above and 450°C or below. The lower limit of the tempering temperature is preferably (Ta + 10°C) or above. The upper limit of the tempering temperature is preferably 420°C or below.

[Holding time at the tempering temperature: 10 seconds or more and 1000 seconds or less]

[0074] When the holding time at the tempering temperature is less than 10 seconds, austenite stabilization is insufficient and retained austenite cannot be obtained as desired. Consequently, bendability is lowered. When the holding time at the tempering temperature is more than 1000 seconds, martensite is excessively tempered to make it difficult to achieve 1180 MPa or higher TS. Thus, the holding time at the tempering temperature is limited to 10 seconds or more and 1000 seconds or less. The lower limit of the holding time at the tempering temperature is preferably 50 seconds or more. The upper limit of the holding time at the tempering temperature is preferably 800 seconds or less.

[0075] Post-temper cooling is not particularly limited and the steel sheet may be cooled to a desired temperature in an appropriate manner. Incidentally, the desired temperature is preferably about room temperature.

[0076] Furthermore, the high strength steel sheet described above may be worked under conditions where the amount of equivalent plastic strain is 0.10% or more and 5.00% or less. The working may be followed by reheating at 100°C or above and 400°C or below.

[0077] When the high strength steel sheet is a product that is traded, the steel sheet is usually traded after being cooled to room temperature.

[0078] The high strength steel sheet may be subjected to coating treatment during annealing or after annealing.

[0079] For example, the coating treatment during annealing may be hot-dip galvanizing treatment performed when the annealed steel sheet is being cooled or has been cooled from 700°C to 600°C at an average cooling rate of 20°C/s or more.

The hot-dip galvanizing treatment may be followed by alloying. For example, the coating treatment after annealing may be Zn-Ni electrical alloy coating treatment or pure Zn electroplated coating treatment performed after tempering. A coated layer may be formed by electroplated coating, or hot-dip zinc-aluminum-magnesium alloy coating may be applied. While the coating treatment has been described above focusing on zinc coating, the types of coating metals, such as Zn coating and Al coating, are not particularly limited. Other conditions in the manufacturing method are not particularly limited. From the point of view of productivity, the series of treatments including annealing, hot-dip galvanizing, and alloying treatment of the coated zinc layer is preferably performed on hot-dip galvanizing line CGL (continuous galvanizing line). To control the coating weight of the coated layer, the hot-dip galvanizing treatment may be followed by wiping. Conditions for operations, such as coating, other than those conditions described above may be determined in accordance with the usual hot-dip galvanizing technique.

[0080] After the coating treatment after annealing, the steel sheet may be worked again under conditions where the amount of equivalent plastic strain is 0.10% or more and 5.00 or less. The working may be followed by reheating at 100°C or above and 400°C or below.

EXAMPLES

[0081] Steels having a chemical composition described in Table 1 and 2, with the balance being Fe and incidental impurities, were smelted in a converter and were continuously cast into slabs. Next, the slabs obtained were heated, hot rolled, pickled, cold rolled, and subjected to annealing treatment described in Table 3 and 4. High strength cold rolled steel sheets having a sheet thickness of 0.6 to 2.2 mm were thus obtained. During annealing, the steel sheet was subjected to bending and unbending with a roll having a radius of 300 mm. In the temperature range from 499°C to Ms, the steel sheet was subjected to bending and unbending with a roll having a radius of 300 mm. Incidentally, some of the steel sheets were subjected to coating treatment during or after annealing.

[0082] The high strength cold rolled steel sheets obtained as described above were used as test steels. Tensile characteristics, bendability, flatness in the width direction, and working embrittlement resistance were evaluated in accordance with the following test methods.

[Table 1]

Steels	Chemical composition (mass%)													
	C	Si	Mn	P	S	N	O	Al	Ti	B	Nb	Cu	Others	
A	0.242	1.02	2.69	0.006	0.0012	0.002	0.006	0.034						INV. EX.
B	0.246	1.31	2.67	0.005	0.0005	0.003	0.002	0.030						INV. EX.
C	0.248	1.35	2.66	0.008	0.0013	0.007	0.002	0.055						INV. EX.
D	0.249	1.40	2.84	0.006	0.0009	0.006	0.006	0.015						INV. EX.
E	0.236	1.00	2.86	0.012	0.0009	0.002	0.004	0.036						INV. EX.
F	0.034	1.19	2.48	0.015	0.0012	0.005	0.004	0.031						INV. EX.
G	<u>0.025</u>	1.19	2.61	0.012	0.0009	0.004	0.002	0.036						COMP. EX.
H	0.466	1.23	2.50	0.013	0.0012	0.006	0.006	0.034						INV. EX.
I	<u>0.504</u>	1.34	2.43	0.007	0.0014	0.001	0.003	0.028						COMP. EX.
J	0.268	0.74	2.81	0.006	0.0008	0.003	0.002	0.028						INV. EX.
K	0.226	<u>0.41</u>	2.59	0.012	0.0014	0.004	0.006	0.031						COMP. EX.
L	0.235	2.36	2.84	0.009	0.0012	0.004	0.002	0.034						INV. EX.
M	0.240	<u>2.58</u>	2.87	0.009	0.0009	0.001	0.005	0.051						COMP. EX.
N	0.241	1.03	1.57	0.012	0.0011	0.003	0.006	0.055						INV. EX.
O	0.246	1.34	<u>1.41</u>	0.011	0.0014	0.002	0.007	0.018						COMP. EX.
P	0.229	1.32	4.75	0.007	0.0010	0.005	0.001	0.014						INV. EX.
Q	0.223	1.32	<u>5.16</u>	0.007	0.0008	0.002	0.004	0.031						COMP. EX.
R	0.224	1.08	2.75	0.097	0.0012	0.004	0.007	0.017						INV. EX.
S	0.225	1.39	2.54	<u>0.109</u>	0.0011	0.005	0.001	0.050						COMP. EX.
T	0.230	1.05	2.43	0.010	0.0195	0.002	0.003	0.015						INV. EX.
U	0.239	1.29	2.42	0.007	<u>0.0204</u>	0.003	0.006	0.044						COMP. EX.
V	0.246	1.18	2.63	0.011	0.0011	0.005	0.003	0.924						INV. EX.
W	0.265	1.15	2.74	0.006	0.0007	0.007	0.007	<u>1.049</u>						COMP. EX.
X	0.261	1.21	2.59	0.009	0.0010	0.0090	0.005	0.033						INV. EX.
Y	0.252	1.36	2.73	0.010	0.0007	<u>0.0110</u>	0.005	0.049						COMP. EX.

(continued)

Steels	Chemical composition (mass%)													
	C	Si	Mn	P	S	N	O	Al	Ti	B	Nb	Cu	Others	
Z	0.238	1.09	2.65	0.012	0.0013	0.004	0.0090	0.019						INV. EX.
AA	0.263	1.21	2.70	0.009	0.0008	0.002	<u>0.0110</u>	0.058						COMP. EX.
AB	0.245	1.11	2.44	0.007	0.0011	0.006	0.003	0.045						INV. EX.
AC	0.252	1.08	2.71	0.015	0.0012	0.007	0.004	0.028	0.003					INV. EX.
AD	0.238	1.25	2.71	0.013	0.0012	0.004	0.004	0.052	0.195					INV. EX.
AE	0.227	1.04	2.75	0.009	0.0013	0.002	0.006	0.041	<u>0.212</u>					COMP. EX.
AF	0.259	1.16	2.52	0.007	0.0014	0.005	0.004	0.058		0.0003				INV. EX.
AG	0.249	1.29	2.65	0.011	0.0015	0.005	0.002	0.054		0.0072				INV. EX.
AH	0.229	1.18	2.77	0.013	0.0014	0.001	0.005	0.027		<u>0.0105</u>				COMP. EX.
AI	0.252	1.32	2.45	0.013	0.0005	0.003	0.005	0.052			0.003			INV. EX.
AJ	0.251	1.02	2.87	0.013	0.0011	0.003	0.002	0.037			0.182			INV. EX.
AK	0.232	1.30	2.53	0.013	0.0013	0.005	0.005	0.020			<u>0.213</u>			COMP. EX.
AL	0.225	1.23	2.42	0.008	0.0005	0.005	0.003	0.045				0.02		INV. EX.
AM	0.242	1.08	2.78	0.010	0.0009	0.002	0.004	0.041				0.92		INV. EX.
Underlines indicate being outside the range of the present invention.														

[Table 2]

Steels	Chemical composition (mass%)													
	C	Si	Mn	P	S	N	O	Al	Ti	B	Nb	Cu	Others	
AN	0.257	1.32	2.53	0.010	0.0015	0.002	0.003	0.032				1.12		COMP. EX.
AO	0.251	1.07	2.82	0.006	0.0014	0.005	0.003	0.012					V:0.024	INV. EX.
AP	0.255	1.26	2.73	0.009	0.0011	0.002	0.004	0.035					Ta:0.06	INV. EX.
AQ	0.226	1.22	2.47	0.013	0.0014	0.007	0.006	0.044					W:0.07	INV. EX.
AR	0.240	1.28	2.65	0.009	0.0008	0.006	0.004	0.044					Cr:0.17	INV. EX.
AS	0.248	1.25	2.70	0.010	0.0006	0.004	0.006	0.023					Mo:0.54	INV. EX.
AT	0.229	1.09	2.80	0.011	0.0009	0.003	0.001	0.043					Co:0.008	INV. EX.
AU	0.245	1.19	2.79	0.007	0.0014	0.005	0.005	0.042					Ni:0.75	INV. EX.
AV	0.228	1.31	2.57	0.011	0.0013	0.004	0.003	0.049					Sn:0.019	INV. EX.
AW	0.268	1.15	2.67	0.006	0.0013	0.003	0.002	0.012					Sb:0.056	INV. EX.
AX	0.242	1.16	2.75	0.014	0.0010	0.002	0.003	0.012					Ca:0.0024	INV. EX.
AY	0.240	1.10	2.77	0.014	0.0006	0.003	0.005	0.011					Mg:0.0090	INV. EX.
AZ	0.234	1.18	2.90	0.008	0.0012	0.002	0.002	0.052					Zr:0.064	INV. EX.
BA	0.233	1.38	2.75	0.012	0.0007	0.005	0.005	0.032					Te:0.075	INV. EX.
BB	0.268	1.02	2.54	0.006	0.0013	0.004	0.002	0.042					Hf:0.04	INV. EX.
BC	0.230	1.28	2.78	0.011	0.0014	0.004	0.004	0.052					REM:0.0079	INV. EX.
BD	0.227	1.17	2.60	0.011	0.0008	0.004	0.005	0.055					Bi:0.164	INV. EX.
BE	0.227	1.17	2.61	0.014	0.0014	0.007	0.007	0.021					Zn:0.037	INV. EX.
BF	0.235	1.33	2.82	0.008	0.0011	0.001	0.001	0.021					Pb:0.086	INV. EX.
BG	0.239	1.26	2.82	0.012	0.0012	0.003	0.002	0.013					As:0.035	INV. EX.
BH	0.248	1.30	2.61	0.010	0.0006	0.006	0.007	0.055					Ge:0.032	INV. EX.
BI	0.221	1.18	2.86	0.012	0.0008	0.002	0.003	0.040					Sr:0.050	INV. EX.
BJ	0.240	1.14	2.45	0.010	0.0008	0.002	0.005	0.026					Cs:0.012	INV. EX.
BK	0.262	1.15	2.57	0.011	0.0009	0.006	0.005	0.011						INV. EX.
BL	0.240	1.34	2.88	0.007	0.0006	0.006	0.002	0.055						INV. EX.
BM	0.220	1.36	2.74	0.011	0.0011	0.004	0.003	0.043						INV. EX.
BN	0.242	1.39	2.72	0.009	0.0007	0.002	0.006	0.016						INV. EX.
BO	0.224	1.02	2.66	0.011	0.0006	0.007	0.004	0.052						INV. EX.
Underlines indicate being outside the range of the present invention.														

[Table 3]

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type"	
1	A	861	56	10	68	64	3	323	243	208	15	17	339	247	1.4	CR	INV. EX.
2	B	777	125	10	66	73	3	321	241	190	14	12	297	299	1.4	CR	INV. EX.
3	B	777	135	10	51	69	3	321	241	187	17	16	294	208	1.4	CR	INV. EX.
4	B	744	168	10	78	38	3	321	241	177	18	12	278	214	1.4	CR	COMP. EX.
5	B	946	77	10	57	64	3	321	241	189	13	13	261	190	1.4	CR	INV. EX.
6	B	952	195	10	66	49	3	321	241	182	13	12	329	245	1.4	CR	COMP. EX.
7	B	863	30	10	77	39	3	321	241	187	18	11	322	191	1.4	CR	INV. EX.
8	B	871	3	10	71	76	3	321	241	185	13	8	349	116	1.4	CR	COMP. EX.
9	B	875	837	10	76	54	3	321	241	184	15	11	280	101	1.4	CR	INV. EX.
10	B	876	1008	10	67	60	3	321	241	196	13	14	325	238	1.4	CR	COMP. EX.
11	B	875	107	1	69	58	3	321	241	184	18	10	261	206	1.4	CR	INV. EX.
12	B	870	73	0	64	80	3	321	241	200	13	18	303	270	1.4	CR	COMP. EX.

(continued)

No-s.	Stee-ls	Anneal-ing temp. (°C)	Holding time at anneal-ing temp. (s)	Count of bending and unbend-ing during anneal-ing (times)	Average cooling rate in tempera-ture range of 700-600°-C (°C/s)	Average cooling rate in tempera-ture range of 499°C-Ms (°C/s)	Count of bending and unbend-ing in tempera-ture range of 499°C-Ms (times)	Ms (°-C)	(M-s-8-0) (°C)	Cool-ing stop temp. Ta (°C)	Average cooling rate in tempera-ture range of Ms-Ta (°C/s)	Tension applied to steel sheet in tempera-ture range of Ms-Ta (MPa)	Temper-ing temp. (°C)	Holding time at temper-ing temp. (s)	Sheet thick-ness (mm)	Typ-e"	
13	B	880	148	15	53	55	3	32-1	241	189	14	16	332	267	1.4	CR	INV. EX.
14	B	877	64	15	78	34	3	32-1	241	185	13	14	292	242	1.4	CR	INV. EX.
15	B	880	83	3	38	53	3	32-1	241	186	19	18	259	117	1.4	CR	INV. EX.
16	B	860	197	3	12	53	3	32-1	241	174	10	17	345	294	1.4	CR	COM-P. EX.
17	B	870	80	3	72	70	3	32-1	241	171	17	16	309	269	1.4	CR	INV. EX.
18	B	873	126	3	76	36	3	32-1	241	194	16	17	347	237	1.4	CR	INV. EX.
19	B	866	140	3	64	22	3	32-1	241	193	14	18	320	298	1.4	CR	INV. EX.
20	B	869	169	3	55	16	3	32-1	241	182	11	15	335	212	1.4	CR	COM-P. EX.
21	B	861	72	3	72	71	3	32-1	241	175	95	13	305	211	1.4	CR	INV. EX.
22	B	866	111	3	55	34	3	32-1	241	179	19	15	179	271	1.4	CR	INV. EX.
23	B	862	180	3	79	49	1	32-1	241	203	17	14	308	136	1.4	CR	INV. EX.
24	B	868	198	3	66	64	0	32-1	241	177	15	18	302	249	1.4	CR	COM-P. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type"	
25	B	863	62	3	63	48	15	321	241	193	11	13	314	177	1.4	CR	INV. EX.
26	B	873	184	3	73	72	15	321	241	173	12	16	280	109	1.4	CR	INV. EX.
27	B	874	191	3	72	72	3	321	241	105	20	15	349	134	1.4	CR	INV. EX.
28	B	869	150	3	50	43	3	321	241	97	19	12	341	212	1.4	CR	COMP. EX.
29	B	879	103	3	56	62	3	321	241	240	15	17	343	221	1.4	CR	INV. EX.
30	B	878	176	3	79	78	3	321	241	244	15	13	332	284	1.4	CR	COMP. EX.
31	B	869	81	3	70	61	3	321	241	199	17	12	273	137	1.4	CR	INV. EX.
32	B	879	151	3	74	67	3	321	241	186	19	17	336	153	1.4	CR	INV. EX.
33	B	879	134	3	70	56	3	321	241	175	135	11	284	253	1.4	CR	INV. EX.
34	B	878	102	10	79	70	3	321	241	191	154	14	337	221	1.4	CR	COMP. EX.
35	B	872	88	10	76	62	3	321	241	209	17	6	336	166	1.4	CR	INV. EX.
36	B	878	128	10	57	62	3	321	241	174	20	2	276	164	1.4	CR	COMP. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type"	
37	B	868	95	10	59	30	3	321	241	197	14	90	347	251	1.4	CR	INV. EX.
38	B	860	115	10	56	63	3	321	241	200	16	92	325	176	1.4	CR	INV. EX.
39	B	866	187	10	67	53	3	321	241	205	18	11	205	265	1.4	CR	INV. EX.
40	B	868	125	10	53	64	3	321	241	175	19	15	175	140	1.4	CR	INV. EX.
41	B	876	133	10	50	64	3	321	241	200	13	13	435	237	1.4	CR	INV. EX.
42	B	865	120	10	57	37	3	321	241	185	19	8	444	173	1.4	CR	INV. EX.
43	B	865	141	10	50	64	10	321	241	187	18	15	312	27	1.4	CR	INV. EX.
44	B	861	134	3	54	64	10	321	241	192	13	15	269	6	1.4	CR	COMP. EX.
45	B	877	153	3	72	47	10	321	241	194	11	14	275	936	1.4	CR	INV. EX.
46	B	874	82	3	77	73	10	321	241	211	16	10	330	995	1.4	CR	INV. EX.
47	B	868	138	3	65	34	10	321	241	182	11	10	295	254	1.4	CR	INV. EX.
48	B	878	101	3	67	54	10	321	241	196	107	12	338	165	1.6	CR	INV. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type"	
49	C	866	70	3	53	33	10	321	241	206	97	16	280	138	2.0	CR	INV. EX.
50	D	877	85	3	54	41	10	315	235	196	12	16	264	238	1.4	CR	INV. EX.
51	E	870	125	3	69	62	3	320	240	182	13	10	310	270	1.4	CR	INV. EX.
52	F	862	119	3	70	68	3	427	347	288	11	9	345	236	1.4	CR	INV. EX.
53	G	869	70	3	64	38	3	428	348	296	17	9	325	135	1.4	CR	COMP. EX.
54	H	872	125	3	59	51	3	222	142	110	12	12	257	177	1.4	CR	INV. EX.
55	I	865	82	3	77	53	3	206	126	105	13	15	283	210	1.4	CR	COMP. EX.
56	J	872	112	3	59	57	3	307	227	164	17	13	265	127	1.4	CR	INV. EX.

Underlines indicate being outside the range of the present invention.
(*)CR: cold rolled steel sheet (no coating), GI: hot-dip galvanized steel sheet (no alloying of zinc coating), GA: galvannealed steel sheet, EG: electrogalvanized steel sheet

[Table 4]

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type*	
57	K	868	64	3	66	37	3	333	253	209	12	16	277	290	1.4	CR	COMP. EX.
58	L	876	162	3	53	73	3	321	241	205	15	17	339	179	1.4	CR	INV. EX.
59	M	867	79	10	67	65	3	318	238	199	15	10	262	269	1.4	GA	COMP. EX.
60	N	880	118	10	66	32	3	357	277	240	16	9	301	292	1.4	GA	INV. EX.
61	O	871	87	10	64	72	3	360	280	221	20	10	286	207	1.4	GA	COMP. EX.
62	P	868	99	10	56	43	3	266	186	126	18	9	293	284	1.4	GA	INV. EX.
63	Q	867	61	10	52	76	3	256	176	146	13	17	271	194	1.4	GA	COMP. EX.
64	R	873	56	10	67	61	3	329	249	202	17	11	259	162	1.4	CR	INV. EX.
65	S	871	114	3	50	40	3	335	255	205	13	18	293	264	1.4	CR	COMP. EX.
66	T	871	60	3	54	49	3	336	256	211	14	18	254	176	1.4	GA	INV. EX.
67	U	876	195	3	69	59	3	332	252	193	14	14	302	286	1.4	GA	COMP. EX.
68	V	876	72	3	77	46	3	322	242	182	10	10	305	206	1.4	GI	INV. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type*	
69	W	872	195	3	79	58	3	310	230	167	16	15	301	132	1.4	GA	COMP. EX.
70	X	863	89	3	71	65	10	317	237	195	19	13	265	184	1.4	GA	INV. EX.
71	Y	868	70	3	54	61	10	317	237	169	19	8	307	135	1.4	GA	COMP. EX.
72	Z	877	157	3	66	43	10	326	246	176	13	13	259	193	1.4	GA	INV. EX.
73	AA	861	186	3	54	73	10	312	232	167	18	10	307	279	1.4	GI	COMP. EX.
74	AB	862	154	3	74	48	10	329	249	196	12	12	327	174	1.4	GA	INV. EX.
75	AC	872	154	3	51	58	10	317	237	194	11	14	349	185	1.4	GA	INV. EX.
76	AD	865	109	3	59	52	10	324	244	213	17	16	331	180	1.4	GA	INV. EX.
77	AE	872	92	3	77	71	10	328	248	202	13	12	318	112	1.4	GA	COMP. EX.
78	AF	870	147	3	67	68	3	320	240	174	13	11	258	152	1.4	GA	INV. EX.
79	AG	872	113	3	69	53	3	320	240	203	17	13	267	184	1.4	GI	INV. EX.
80	AH	871	175	10	60	36	3	326	246	182	17	14	287	164	1.4	GA	COMP. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type*	
81	AI	861	183	10	72	64	3	325	245	183	17	12	331	234	1.4	GA	INV. EX.
82	AJ	861	78	10	54	70	3	313	233	200	14	18	275	243	1.4	GA	INV. EX.
83	AK	867	51	10	54	78	3	332	252	207	16	11	277	166	1.4	GA	COMP. EX.
84	AL	879	195	10	65	31	3	339	259	189	18	10	273	218	1.4	CR	INV. EX.
85	AM	877	182	10	71	70	3	320	240	195	20	17	261	178	1.4	CR	INV. EX.
86	AN	870	192	10	71	47	3	320	240	189	13	15	346	275	1.4	GA	COMP. EX.
87	AO	799	181	10	55	34	3	314	234	183	13	16	265	158	1.4	GA	INV. EX.
88	AP	917	153	10	78	74	3	315	235	167	11	12	339	275	1.4	GA	INV. EX.
89	AQ	870	19	10	51	40	3	337	257	218	18	16	285	232	1.4	GA	INV. EX.
90	AR	879	870	10	57	78	3	323	243	184	13	10	311	181	1.4	GA	INV. EX.
91	AS	860	187	1	52	30	3	315	235	202	13	14	293	298	1.4	GA	INV. EX.
92	AT	869	182	15	58	32	3	325	245	200	15	16	349	298	1.4	GA	INV. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type*	
93	AU	868	112	3	22	50	3	305	225	186	11	15	277	141	1.5	CR	INV. EX.
94	AV	871	148	3	63	32	3	333	253	210	16	17	306	175	1.6	CR	INV. EX.
95	AW	864	181	10	71	23	3	311	231	194	16	10	318	172	12	CR	INV. EX.
96	AX	862	175	10	64	75	3	321	241	200	15	15	200	284	1.1	CR	INV. EX.
97	AY	874	51	10	64	35	1	321	241	209	19	8	335	277	1.4	CR	INV. EX.
98	AZ	872	56	10	55	71	15	320	240	203	15	15	317	151	1.4	CR	INV. EX.
99	BA	865	99	3	51	61	3	325	245	109	16	17	339	162	1.4	CR	INV. EX.
100	BB	864	166	3	62	40	3	315	235	231	14	13	329	273	12	CR	INV. EX.
101	BC	866	180	10	60	39	3	325	245	198	17	13	291	280	1.1	CR	INV. EX.
102	BD	862	159	10	53	74	3	332	252	203	149	17	337	294	1.4	CR	INV. EX.
103	BE	866	173	3	69	51	3	332	252	190	14	5	307	193	1.5	CR	INV. EX.
104	BF	877	158	3	56	33	3	322	242	197	15	86	316	114	1.6	CR	INV. EX.

(continued)

Nos.	Steels	Annealing temp. (°C)	Holding time at annealing temp. (s)	Count of bending and unbending during annealing (times)	Average cooling rate in temperature range of 700-600°C (°C/s)	Average cooling rate in temperature range of 499°C-Ms (°C/s)	Count of bending and unbending in temperature range of 499°C-Ms (times)	Ms (°C)	(Ms-80) (°C)	Cooling stop temp. Ta (°C)	Average cooling rate in temperature range of Ms-Ta (°C/s)	Tension applied to steel sheet in temperature range of Ms-Ta (MPa)	Tempering temp. (°C)	Holding time at tempering temp. (s)	Sheet thickness (mm)	Type*	
105	BG	876	140	10	61	38	3	320	240	172	13	11	172	172	12	CR	INV. EX.
106	BH	870	190	10	68	52	3	322	242	201	13	11	437	160	1.1	CR	INV. EX.
107	BI	863	175	10	50	75	3	327	247	197	19	17	311	21	1.5	CR	INV. EX.
108	BJ	877	187	10	58	54	3	331	251	221	17	11	325	943	1.6	CR	INV. EX.
109	BK	877	196	10	69	32	12	317	237	196	11	10	302	294	12	EG	INV. EX.
110	BL	878	145	5	78	39	12	318	238	190	15	16	317	141	1.1	GI	INV. EX.
111	BM	867	92	5	77	57	3	331	251	202	13	9	333	138	1.4	EG	INV. EX.
112	BN	863	129	12	55	37	3	322	242	195	94	15	302	134	1.5	GI	INV. EX.
113	BO	876	181	12	51	43	3	332	252	188	103	17	267	162	1.8	GA	INV. EX.

Underlines indicate being outside the range of the present invention.
(*)CR: cold rolled steel sheet (no coating), GI: hot-dip galvanized steel sheet (no alloying of zinc coating), GA: galvannealed steel sheet, EG: electrogalvanized steel sheet

(Microstructure observation)

[0083] The amount of martensite, the amount of retained austenite, the total amount of ferrite and bainitic ferrite, and the average grain size of prior austenite were determined by the methods described hereinabove.

(Proportion of packets having the largest area in prior austenite grains)

[0084] The average proportion of packets having the largest area in prior austenite grains was determined by the method described hereinabove.

(Tensile test)

[0085] A JIS No. 5 test specimen (gauge length: 50 mm, parallel section width: 25 mm) was sampled so that the longitudinal direction of the test specimen would be perpendicular to the rolling direction. A tensile test was performed in accordance with JIS Z 2241 under conditions where the crosshead speed was 1.67×10^{-1} mm/sec. TS was thus measured. In the present invention, 1180 MPa or higher TS was determined to be acceptable.

(Bendability)

[0086] A 30 mm × 100 mm bendability test specimen was sampled and was tested by a V-block method in accordance with JIS Z 2248 to measure the minimum bending radius R that did not cause cracking on the ridge portion of the bend. The bending direction was the longitudinal direction of the test specimen. The minimum bending radius (R) was divided by the sheet thickness (t) to determine the value R/t. Bendability was evaluated as excellent when R/t was 6.0 or less. Here, the presence or absence of cracking was determined by analyzing the ridge portion of the bend top with a digital microscope (RH-2000 manufactured by HIROX CO., LTD.) at ×40 magnification.

(Flatness in the width direction)

[0087] The cold rolled steel sheets obtained as described above were analyzed to measure the flatness in the width direction. The measurement is illustrated in Fig. 2. Specifically, a sheet with a length of 500 mm in the rolling direction (coil width × 500 mm L × sheet thickness) was cut out from the coil and was placed on a surface plate in such a manner that the warp at the ends would face upward. The height on the steel sheet was measured with a contact displacement meter by continuously moving the stylus over the width. Based on the results, the steepness as an index of the flatness of the steel sheet shape was measured as illustrated in Fig. 2. The flatness was rated as "×" when the steepness was more than 0.02, as "o" when the steepness was more than 0.01 and 0.02 or less, and as "◎" when the steepness was 0.01 or less. The steel sheet was evaluated as "excellent in the flatness in the width direction" when the steepness was 0.02 or less.

(Working embrittlement resistance)

[0088] The working embrittlement resistance was evaluated by Charpy test. A Charpy test specimen was a 2 mm deep V-notched test piece that was a stack of steel sheets fastened together with bolts to eliminate any gaps between the steel sheets. The number of steel sheets that were stacked was controlled so that the thickness of the stack as the test piece would be closer to 10 mm. When, for example, the sheet thickness was 1.2 mm, eight sheets were stacked to give a 9.6 mm thick test piece. The sheets for stacking into the Charpy test specimen were sampled so that the width direction would be the longitudinal direction. As an index of the working embrittlement resistance, the ratio $vE_{0\%}/vE_{10\%}$ of the absorbed impact energy at room temperature of the as-produced (unworked) steel sheet to that of the steel sheet after 10% rolling was measured. The working embrittlement resistance was rated as "×" when $vE_{0\%}/vE_{10\%}$ was less than 0.6, as "o" when $vE_{0\%}/vE_{10\%}$ was 0.6 or more and less than 0.7, and as "◎" when $vE_{0\%}/vE_{10\%}$ was 0.7 or more. The Charpy test specimen was evaluated as "excellent in working embrittlement resistance" when $vE_{0\%}/vE_{10\%}$ was 0.6 or more. Conditions other than those described above conformed to JIS Z 2242: 2018.

[0089] The results are described in Tables 5 to 7. As shown in Tables 5 to 7, INVENTIVE EXAMPLES achieved 1180 MPa or higher TS and excellent bendability, flatness in the width direction, and working embrittlement resistance. In contrast, COMPARATIVE EXAMPLES were unsatisfactory in one or more of TS, bendability, flatness in the width direction, and working embrittlement resistance.

[Table 5]

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
1	A	1.4	81	11	7	56	10	1385	5.5	3.9	◎	◎	INV. EX.
2	B	1.4	85	9	4	53	11	1562	4.5	3.2	◎	◎	INV. EX.
3	B	1.4	81	9	10	47	8	1214	4.5	3.2	◎	◎	INV. EX.
4	B	1.4	<u>79</u>	8	<u>13</u>	59	10	<u>1004</u>	5.5	3.9	◎	◎	COMP. EX.
5	B	1.4	84	10	7	59	19	1410	5.5	3.9	◎	○	INV. EX.
6	B	1.4	83	10	5	49	<u>23</u>	1514	4.5	3.2	◎	<u>×</u>	COMP. EX.
7	B	1.4	80	10	10	53	13	1200	4.5	3.2	◎	◎	INV. EX.
8	B	1.4	82	5	<u>13</u>	49	11	<u>1102</u>	5.5	3.9	◎	◎	COMP. EX.
9	B	1.4	84	9	6	59	16	1458	4.5	3.2	◎	○	INV. EX.
10	B	1.4	84	10	5	53	<u>24</u>	1515	5.0	3.6	◎	<u>×</u>	COMP. EX.
11	B	1.4	86	8	5	65	14	1511	3.5	2.5	o	o	INV. EX.
12	B	1.4	87	9	3	<u>91</u>	10	1609	4.0	2.9	<u>×</u>	<u>×</u>	COMP. EX.
13	B	1.4	85	9	5	45	14	1509	4.0	2.9	◎	○	INV. EX.
14	B	1.4	81	11	8	49	8	1364	3.5	2.5	◎	○	INV. EX.
15	B	1.4	83	11	7	64	8	1409	4.0	2.9	o	o	INV. EX.
16	B	1.4	82	9	7	<u>90</u>	13	1407	2.0	1.4	<u>×</u>	<u>×</u>	COMP. EX.

(continued)

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
17	B	1.4	84	10	5	53	14	1513	4.0	2.9	◎	◎	INV. EX.
18	B	1.4	82	9	7	57	11	1405	4.5	3.2	◎	◎	INV. EX.
19	B	1.4	81	8	10	54	14	1201	6.5	4.6	◎	◎	INV. EX.
20	B	1.4	74	9	17	49	14	1047	7.0	5.0	◎	◎	COMP. EX.
21	B	1.4	85	9	5	58	10	1514	5.5	3.9	◎	◎	INV. EX.
22	B	1.4	85	9	5	47	10	1511	1.0	0.7	◎	◎	INV. EX.
23	B	1.4	85	11	4	68	9	1554	7.0	5.0	o	o	INV. EX.
24	B	1.4	82	12	7	89	10	1413	6.0	4.3	×	×	COMP. EX.
25	B	1.4	86	10	3	60	14	1610	6.0	4.3	◎	○	INV. EX.
26	B	1.4	86	10	4	50	13	1559	6.5	4.6	◎	○	INV. EX.
27	B	1.4	92	3	2	46	11	1664	8.0	5.7	◎	◎	INV. EX.
28	B	1.4	95	2	3	55	13	1608	9.0	6.4	◎	◎	COMP. EX.
29	B	1.4	84	14	3	51	11	1604	7.0	5.0	◎	○	INV. EX.
30	B	1.4	81	16	3	48	15	1609	6.0	4.3	◎	×	COMP. EX.
31	B	1.4	85	11	7	54	10	1415	5.0	3.6	◎	◎	INV. EX.
32	B	1.4	88	8	4	55	10	1562	5.0	3.6	◎	◎	INV. EX.
33	B	1.4	89	10	3	70	10	1607	5.0	3.6	o	o	INV. EX.

(continued)

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
34	B	1.4	89	12	2	90	15	1655	6.0	4.3	×	×	COMP. EX.
35	B	1.4	84	9	8	68	10	1358	5.0	3.6	o	o	INV. EX.
36	B	1.4	86	10	3	81	9	1604	5.5	3.9	×	×	COMP. EX.
37	B	1.4	87	8	5	58	8	1510	6.0	4.3	◎	○	INV. EX.
38	B	1.4	88	10	3	52	13	1606	6.5	4.6	◎	○	INV. EX.
39	B	1.4	82	8	8	59	9	1356	5.0	3.6	◎	◎	INV. EX.
40	B	1.4	84	12	5	49	9	1512	3.5	2.5	◎	◎	INV. EX.
41	B	1.4	88	8	4	53	15	1199	6.0	4.3	◎	◎	INV. EX.
42	B	1.4	84	12	6	47	12	1207	5.0	3.6	◎	◎	INV. EX.
43	B	1.4	85	4	8	60	13	1360	8.0	5.7	◎	◎	INV. EX.

Underlines indicate being outside the range of the present invention.

[Table 6]

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
44	B	1.4	95	2	2	59	12	1655	8.5	6.1	◎	◎	COMP. EX.
45	B	1.4	86	9	3	55	10	1207	6.0	4.3	◎	◎	INV. EX.
46	B	1.4	85	9	6	58	14	1195	6.5	4.6	◎	◎	INV. EX.
47	B	1.4	83	11	7	54	15	1408	5.0	3.6	◎	◎	INV. EX.
48	B	1.6	86	8	6	56	9	1456	6.0	3.8	◎	◎	INV. EX.
49	C	2.0	90	9	2	56	10	1665	8.0	4.0	◎	◎	INV. EX.
50	D	1.4	85	11	7	47	13	1440	6.0	4.3	◎	◎	INV. EX.
51	E	1.4	87	8	2	58	11	1627	6.0	4.3	◎	◎	INV. EX.
52	F	1.4	81	10	10	51	12	1189	6.5	4.6	◎	◎	INV. EX.
53	G	1.4	83	5	12	47	10	1103	5.0	3.6	◎	◎	COMP. EX.
54	H	1.4	85	11	5	59	10	1803	6.0	4.3	◎	○	INV. EX.
55	I	1.4	83	8	6	48	14	1995	6.0	4.3	◎	×	COMP. EX.
56	J	1.4	82	10	7	47	11	1211	4.0	2.9	◎	◎	INV. EX.
57	K	1.4	86	9	2	58	14	1175	6.0	4.3	◎	◎	COMP. EX.
58	L	1.4	84	13	2	47	14	1711	5.0	3.6	◎	o	INV. EX.
59	M	1.4	82	16	2	46	14	1749	3.0	2.1	◎	×	COMP. EX.
60	N	1.4	82	10	9	59	15	1188	6.5	4.6	◎	◎	INV. EX.

(continued)

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
61	O	1.4	72	9	19	56	10	1011	7.0	5.0	◎	◎	COMP. EX.
62	P	1.4	85	10	5	46	9	1602	6.0	4.3	◎	○	INV. EX.
63	Q	1.4	88	10	4	48	9	1669	5.5	3.9	◎	×	COMP. EX.
64	R	1.4	82	10	8	52	10	1284	3.0	2.1	◎	○	INV. EX.
65	S	1.4	88	10	4	46	10	1491	0.5	0.4	◎	×	COMP. EX.
66	T	1.4	85	12	3	56	15	1520	4.0	2.9	◎	○	INV. EX.
67	U	1.4	86	9	4	49	8	1525	3.0	2.1	◎	×	COMP. EX.
68	V	1.4	87	11	3	47	11	1639	6.5	4.6	◎	○	INV. EX.
69	W	1.4	83	9	8	57	9	1466	5.5	3.9	◎	×	COMP. EX.
70	X	1.4	86	11	4	45	15	1587	5.5	3.9	◎	○	INV. EX.
71	Y	1.4	83	10	8	60	14	1382	4.0	2.9	◎	×	COMP. EX.
72	Z	1.4	85	8	4	49	13	1515	4.5	3.2	◎	○	INV. EX.
73	AA	1.4	85	10	7	54	9	1460	5.5	3.9	◎	×	COMP. EX.
74	AB	1.4	87	12	5	58	14	1479	5.0	3.6	◎	◎	INV. EX.
75	AC	1.4	86	11	5	50	10	1193	5.5	3.9	◎	◎	INV. EX.
76	AD	1.4	85	8	5	57	10	1488	6.0	4.3	◎	○	INV. EX.

(continued)

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
77	AE	1.4	86	10	4	52	13	1879	6.0	4.3	◎	<u>×</u>	COMP. EX.
78	AF	1.4	85	11	6	56	12	1197	6.0	4.3	◎	◎	INV. EX.
79	AG	1.4	85	12	5	49	10	1514	6.0	4.3	◎	○	INV. EX.
80	AH	1.4	86	11	2	49	13	1880	4.5	3.2	◎	<u>×</u>	COMP. EX.
81	AI	1.4	81	12	7	55	14	1212	6.0	4.3	◎	◎	INV. EX.
82	AJ	1.4	89	10	2	47	10	1668	5.0	3.6	◎	○	INV. EX.
83	AK	1.4	87	9	3	57	14	1892	5.0	3.6	◎	<u>×</u>	COMP. EX.
84	AL	1.4	80	11	8	58	12	1195	4.5	3.2	◎	◎	INV. EX.
85	AM	1.4	87	9	5	50	11	1492	5.5	3.9	◎	○	INV. EX.
86	AN	1.4	88	11	3	51	14	1851	5.5	3.9	◎	<u>×</u>	COMP. EX.

Underlines indicate being outside the range of the present invention.

[Table 7]

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
87	AO	1.4	81	8	9	55	9	1194	4.0	2.9	◎	◎	INV. EX.
88	AP	1.4	86	11	6	54	16	1493	5.5	3.9	◎	○	INV. EX.
89	AQ	1.4	82	9	9	54	15	1195	5.5	3.9	◎	◎	INV. EX.
90	AR	1.4	87	9	4	54	17	1541	5.0	3.6	◎	○	INV. EX.
91	AS	1.4	81	10	7	48	13	1416	6.0	4.3	○	○	INV. EX.
92	AT	1.4	82	11	8	49	12	1305	7.5	5.4	◎	◎	INV. EX.
93	AU	1.5	86	10	3	63	14	1611	6.5	4.3	○	○	INV. EX.
94	AV	1.6	83	12	7	58	10	1355	5.5	3.4	◎	◎	INV. EX.
95	AW	1.2	81	10	10	46	14	1202	4.0	3.3	◎	◎	INV. EX.
96	AX	1.1	88	11	3	53	11	1594	4.0	3.6	◎	◎	INV. EX.
97	AY	1.4	82	10	6	63	10	1438	5.0	3.6	○	○	INV. EX.
98	AZ	1.4	83	10	6	49	13	1426	7.5	5.4	◎	◎	INV. EX.
99	BA	1.4	90	4	5	48	11	1481	8.0	5.7	◎	◎	INV. EX.

(continued)

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
100	BB	1.2	83	13	4	52	11	1602	4.5	3.8	◎	○	INV. EX.
101	BC	1.1	85	8	7	47	14	1374	5.0	4.5	◎	◎	INV. EX.
102	BD	1.4	85	10	4	70	12	1484	3.0	2.1	○	○	INV. EX.
103	BE	1.5	83	9	6	69	14	1384	7.0	4.7	○	○	INV. EX.
104	BF	1.6	87	11	5	52	12	1483	8.5	5.3	◎	◎	INV. EX.
105	BG	1.2	85	10	4	47	11	1541	5.5	4.6	◎	◎	INV. EX.
106	BH	1.1	87	11	3	55	9	1217	4.0	3.6	◎	◎	INV. EX.
107	BI	1.5	88	3	5	46	12	1436	8.5	5.7	◎	◎	INV. EX.
108	BJ	1.6	81	9	8	56	11	1201	7.0	4.4	◎	◎	INV. EX.
109	BK	1.2	85	11	4	50	15	1590	5.5	4.6	◎	◎	INV. EX.
110	BL	0.6	86	8	2	59	11	1661	2.5	4.2	◎	◎	INV. EX.
111	BM	2.2	84	8	5	47	12	1441	8.0	3.6	◎	◎	INV. EX.
112	BN	1.5	86	12	4	51	10	1558	6.0	4.0	◎	◎	INV. EX.

(continued)

Nos.	Steels	Sheet thickness (mm)	Martensite (area%)	Retained austenite (vol%)	Total of ferrite and bainitic ferrite (area%)	Average proportion of packets having the largest area in prior austenite grains (area%)	Average grain size of prior austenite (μm)	TS (MPa)	Limiting bending R (mm)	R/t	Flatness in width direction	Working embrittlement resistance	
113	BO	1.8	88	9	3	52	13	1530	8.5	4.7	◎	◎	INV. EX.

Underlines indicate being outside the range of the present invention.

Claims

1. A high strength steel sheet having a chemical composition comprising, in mass%,

   C: 0.030% or more and 0.500% or less,
   Si: 0.50% or more and 2.50% or less,
   Mn: 1.50% or more and 5.00% or less,
   P: 0.100% or less,
   S: 0.0200% or less,
   Al: 1.000% or less,
   N: 0.0100% or less, and
   O: 0.0100% or less,
   a balance being Fe and incidental impurities,
   the high strength steel sheet being such that in a region at 1/4 sheet thickness,
   an area fraction of martensite is 80% or more,
   a volume fraction of retained austenite is 3% or more and 15% or less,
   an area fraction of a total of ferrite and bainitic ferrite is 10% or less,
   an average grain size of prior austenite is 20 um or less, and
   an average of proportions of packets having the largest area in prior austenite grains is 70% by area or less of the prior austenite grain.

2. The high strength steel sheet according to claim 1, wherein the chemical composition further comprises at least one element selected from, in mass%,

   Ti: 0.200% or less, Nb: 0.200% or less,
   V: 0.200% or less, Ta: 0.10% or less,
   W: 0.10% or less, B: 0.0100% or less,
   Cr: 1.00% or less, Mo: 1.00% or less,
   Co: 0.010% or less, Ni: 1.00% or less,
   Cu: 1.00% or less, Sn: 0.200% or less,
   Sb: 0.200% or less, Ca: 0.0100% or less,
   Mg: 0.0100% or less, REM: 0.0100% or less,
   Zr: 0.100% or less, Te: 0.100% or less,
   Hf: 0.10% or less, and Bi: 0.200% or less.

3. The high strength steel sheet according to claim 1 or 2, which has a coated layer on a surface of the steel sheet.

4. A method for manufacturing the high strength steel sheet according to claim 1 or 2, the method comprising:

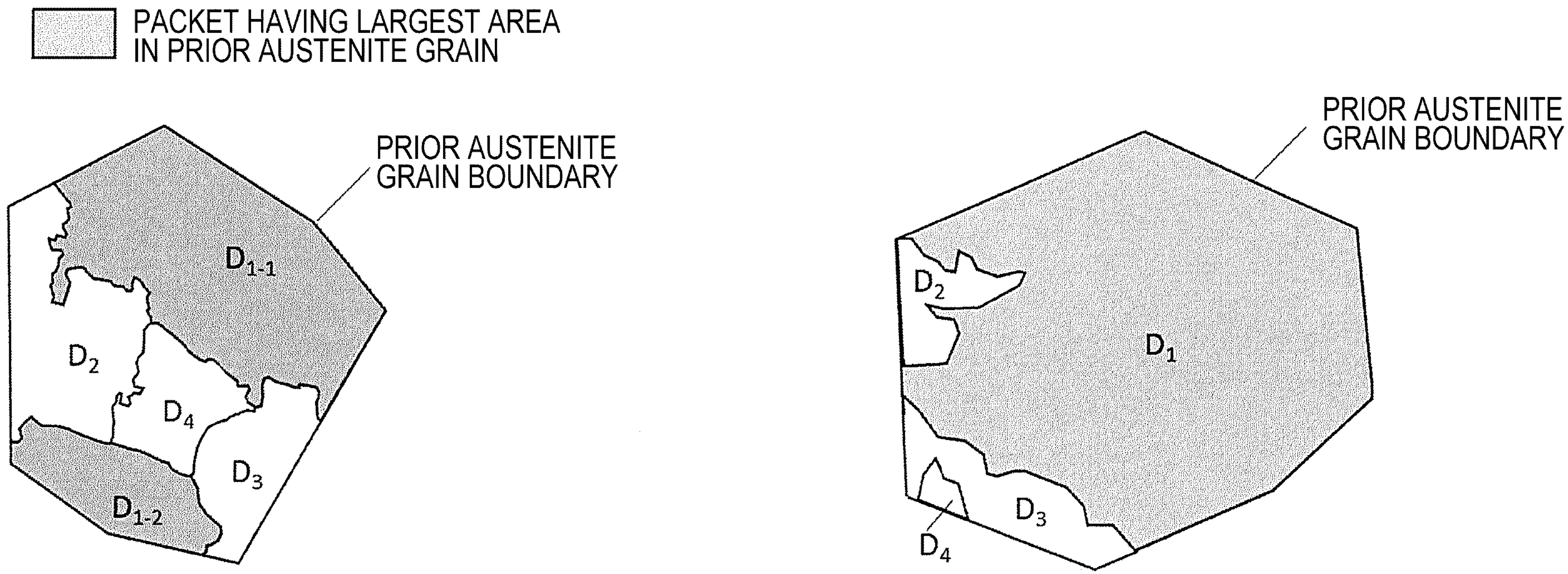
   providing a cold rolled steel sheet produced by subjecting a steel having the chemical composition to hot rolling, pickling, and cold rolling;
   annealing the steel sheet by heating at an annealing temperature of 750°C or above and 950°C or below for a holding time at the annealing temperature of 10 seconds or more and 1000 seconds or less;
   bending and unbending the steel sheet 1 to 15 times in total with a roll having a radius of 800 mm or less during the annealing;
   cooling the steel sheet at an average cooling rate of 20°C/s or more in a temperature range from 700°C to 600°C and at an average cooling rate of 20°C/s or more in a temperature range from 499°C to Ms;
   bending and unbending the steel sheet in the temperature range from 499°C to Ms, 1 to 15 times in total with a roll having a radius of 800 mm or less;
   cooling the steel sheet at an average cooling rate of 150°C/s or less in a temperature range from Ms to a cooling stop temperature Ta;
   applying a tension to the steel sheet in the temperature range from Ms to the cooling stop temperature Ta while controlling the tension to 5 MPa or more and 100 MPa or less,
   the cooling stop temperature Ta being 100°C or above and (Ms - 80°C) or below where Ms is martensite start temperature (°C) defined by formula (1); and
   tempering the steel sheet at a tempering temperature of Ta or above and 450°C or below for a holding time at the tempering temperature of 10 seconds or more and 1000 seconds or less,

$$Ms = 519 - 474 \times [\% C] - 30.4 \times [\% Mn] - 12.1 \times [\% Cr] - 7.5 \times [\% Mo] - 17.7 \times [\% Ni] \quad (1)$$

wherein [% C], [% Mn], [% Cr], [% Mo], and [% Ni] indicate the contents (mass%) of C, Mn, Cr, Mo, and Ni, respectively, and are zero when the element is absent.

5. The method for manufacturing the high strength steel sheet according to claim 4, further comprising performing a coating treatment.

FIG. 1

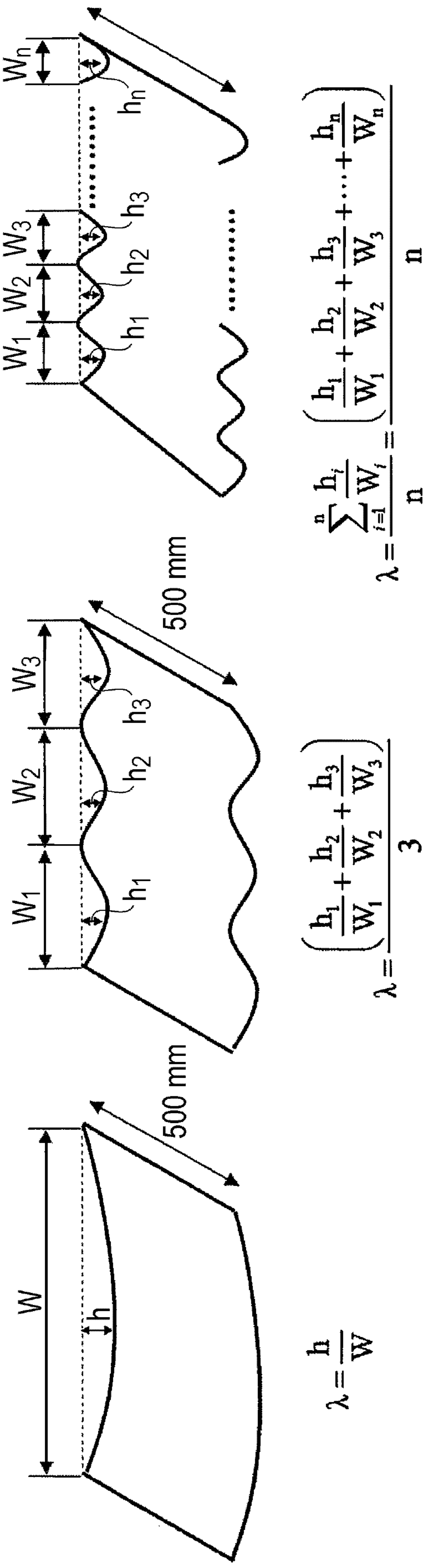


$$\text{(PROPORTION OF PACKET HAVING LARGEST AREA IN PRIOR AUSTENITE GRAIN)} = \frac{(D_{1\text{-}1} + D_{1\text{-}2})}{(D_{1\text{-}1} + D_{1\text{-}2} + D_2 + D_3 + D_4)} \times 100$$

$$\text{(PROPORTION OF PACKET HAVING LARGEST AREA IN PRIOR AUSTENITE GRAIN)} = \frac{D_1}{(D_1 + D_2 + D_3 + D_4)} \times 100$$

PACKET HAVING LARGEST AREA IN PRIOR AUSTENITE GRAIN

FIG. 2


W
h
500 mm
$\lambda = \frac{h}{W}$
W_1
W_2
W_3
h_1
h_2
h_3
500 mm
$\lambda = \frac{\left(\frac{h_1}{W_1} + \frac{h_2}{W_2} + \frac{h_3}{W_3}\right)}{3}$
W_n
h_n
$\lambda = \frac{\sum_{i=1}^{n} \frac{h_i}{W_i}}{n} = \frac{\left(\frac{h_1}{W_1} + \frac{h_2}{W_2} + \frac{h_3}{W_3} + \cdots + \frac{h_n}{W_n}\right)}{n}$

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/002916

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/00(2006.01)i; ***C21D 9/46***(2006.01)i; ***C22C 38/06***(2006.01)i; ***C22C 38/60***(2006.01)i
FI: C22C38/00 301U; C21D9/46 F; C21D9/46 J; C22C38/00 301T; C22C38/06; C22C38/60

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 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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 2018/216522 A1 (KOBE STEEL LTD) 29 November 2018 (2018-11-29) claims	1-5
A	WO 2021/070925 A1 (NIPPON STEEL CORP) 15 April 2021 (2021-04-15) claims	1-5
A	WO 2020/158066 A1 (JFE STEEL CORP) 06 August 2020 (2020-08-06) claims	1-5
A	WO 2018/124157 A1 (JFE STEEL CORP) 05 July 2018 (2018-07-05) claims	1-5
P, A	WO 2022/209519 A1 (JFE STEEL CORP) 06 October 2022 (2022-10-06) claims, paragraphs [0054]-[0058], [0068]-[0074]	1-5

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 April 2023	**18 April 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/002916

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2018/216522 A1	29 November 2018	EP 3633058 A1 claims US 2020/0071787 A1 CN 110651062 A JP 2018-197380 A	
WO 2021/070925 A1	15 April 2021	EP 4043596 A1 claims US 2022/0290269 A1 CN 114207169 A	
WO 2020/158066 A1	06 August 2020	EP 3889282 A1 claims US 2022/0081734 A1 CN 113366133 A	
WO 2018/124157 A1	05 July 2018	EP 3564400 A1 claims US 2020/0190617 A1 CN 110121568 A	
WO 2022/209519 A1	06 October 2022	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 4947176 B **[0009]**
- JP 6525114 B **[0009]**
- JP 6777272 B **[0009]**
- JP 6338025 B **[0009]**

Non-patent literature cited in the description

- *Journal of Smart Processing*, 2013, vol. 2 (3), 110-118 **[0010]**