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(54) **HOT-ROLLED STEEL PLATE**

(57) This hot-rolled steel sheet has a predetermined chemical composition and a microstructure, in which, in a texture of a region from a surface to the depth of 1/8 of the sheet thickness from the surface, pole densities of {001}<110>, {111}<110>, and {112}<110> orientation

groups are 2.0 to 8.0, in a texture of a region from the depth of 1/8 of the sheet thickness from the surface to a depth of 1/2 of the sheet thickness from the surface, a pole density of a {110}<112> orientation is 2.0 to 4.0, and a tensile strength is 980 MPa or more.

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Description

[Technical Field of the Invention]

[0001] The present invention relates to a hot-rolled steel sheet.

[0002] Priority is claimed on Japanese Patent Application No. 2021-168627, filed October 14, 2021, the content of which is incorporated herein by reference.

[Background Art]

[0003] In consideration of global environment protection, the weights of automobile bodies have been reduced in order to improve fuel efficiency of automobiles. In order to further reduce the weight of automobile bodies, it is necessary to increase the strength of steel sheets applied to automobile bodies. However, generally, when the strength of steel sheets increases, the formability deteriorates.

[0004] As a method of improving formability of steel sheets, there is a method of incorporating retained austenite into a microstructure of a steel sheet. However, when the microstructure of the steel sheet contains retained austenite, the ductility is improved, but isotropy in ductility and hole expansibility may deteriorate. When bend molding, hole expansion processing and burring processing are performed, decreasing anisotropy in ductility, that is, excellent isotropy in ductility is required. In addition, when such as the above processing are performed, excellent hole expansibility is also required.

[0005] For example, Patent Document 1 discloses a hot-rolled steel sheet having a microstructure which contains bainite as the highest area fraction, and contains hard phases constituted by martensite and/or austenite in an amount of, in area fraction, equal to or more than 3% and less than 20%, wherein 60% or more of the hard phases present in a sheet-thickness central portion have an aspect ratio of 3 or more, wherein the aspect ratio is defined by the length of the major axis of the hard phase/the length of the minor axis of the hard phase, the hard phases present in the sheet-thickness central portion have a length in a rolling direction of less than 20 μm , and the sum of X-ray random intensity ratios of <011> orientation and <111> orientation as viewed from the rolling direction is 3.5 or more, and an X-ray random intensity ratio of <001> orientation as viewed from the rolling direction is 1.0 or less.

[Prior Art Document]

[Patent Document]

[0006] [Patent Document 1] PCT International Publication No. WO2016/010004

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0007] However, in Patent Document 1, it is necessary to further improve a strength in order to further reduce the weights of automobile bodies. In addition, in Patent Document 1, isotropy in ductility is not considered.

[0008] An object of the present invention is to provide a hot-rolled steel sheet having high strength, excellent isotropy in ductility, and hole expansibility.

[Means for Solving the Problem]

[0009] In view of the above circumstances, the present inventors conducted extensive studies regarding the relationship between a chemical composition and a microstructure of a hot-rolled steel sheet and mechanical properties, and as a result, the following findings were obtained, and the present invention was completed.

[0010] The present inventors found that in order to improve isotropy in ductility and hole expansibility of a hot-rolled steel sheet, it is important to control a texture in a surface layer region and a internal region of the hot-rolled steel sheet. In addition, the present inventors found that in order to control the texture in the surface layer region and the internal region of the hot-rolled steel sheet, it is especially effective to control final rolling conditions.

[0011] The gist of the present invention made on the basis of the above-mentioned findings is as follows.

(1) A hot-rolled steel sheet according to an aspect of the present invention includes, as a chemical composition, by mass%:

C: 0.100% to 0.350%;

Si: 0.010% to 3.00%;
Mn: 1.00% to 4.00%;
sol. Al: 0.001% to 2.000%;
Si+sol.Al: 1.00% or more;
5 Ti: 0.010% to 0.380%;
P: 0.100% or less;
S: 0.0300% or less;
N: 0.1000% or less;
O: 0.0100% or less;
10 Nb: 0% to 0.100%;
V: 0% to 0.500%;
Cu: 0% to 2.00%;
Cr: 0% to 2.00%;
Mo: 0% to 1.00%;
15 Ni: 0% to 2.00%;
B: 0% to 0.0100%;
Ca: 0% to 0.0200%;
Mg: 0% to 0.0200%;
REM: 0% to 0.1000%;
20 Bi: 0% to 0.020%;
one, two or more of Zr, Co, Zn and W: 0 to 1.00% in total,
Sn: 0% to 0.050%; and
a remainder comprising Fe and impurities,
in which a microstructure in a region from a depth of 1/8 of a sheet thickness from a surface to a depth of 3/8
25 of the sheet thickness from the surface comprises, by area%,

retained austenite: 10% to 20%,
fresh martensite: 10% or less, and
bainite: 70% to 90%,
30

in a texture of a region from the surface to the depth of 1/8 of the sheet thickness from the surface,
pole densities of {001}<110>, {111}<110>, and { 112 } < 110> orientation groups are 2.0 to 8.0,
in a texture of a region from the depth of 1/8 of the sheet thickness from the surface to a depth of 1/2 of the
sheet thickness from the surface,
35 a pole density of a { 110}<112> orientation is 2.0 to 4.0, and
a tensile strength of the hot-rolled steel sheet is 980 MPa or more.

(2) In the hot-rolled steel sheet according to (1), the chemical composition may contain, by mass%, one or two or
40 more selected from the group consisting of

Nb: 0.005 to 0.100%,
V: 0.005 to 0.500%,
Cu: 0.01 to 2.00%,
Cr: 0.01 to 2.00%,
45 Mo: 0.01 to 1.00%,
Ni: 0.02 to 2.00%,
B: 0.0001 to 0.0100%,
Ca: 0.0005 to 0.0200%,
Mg: 0.0005 to 0.0200%,
50 REM: 0.0005 to 0.1000%, and
Bi: 0.0005 to 0.020%.

[Effects of the Invention]

55 **[0012]** According to the above-described aspect according to the present invention, it is possible to provide a hot-rolled steel sheet having high strength, and excellent isotropy in ductility and hole expansibility.

[Embodiments of the Invention]

[0013] Hereinafter, a chemical composition and a microstructure of a hot-rolled steel sheet according to the present embodiment will be described in detail. However, the present invention is not limited to only the configuration disclosed in the present embodiment and can be variously modified without departing from the gist of the present invention.

[0014] Numerical limiting ranges described below using "to" include the lower limit and the upper limit in the ranges. Numerical values indicated as "less than" or "more than" do not fall within the numerical range. In addition, % regarding the chemical composition means mass% unless otherwise specified.

Chemical Composition

[0015] The hot-rolled steel sheet according to the present embodiment includes, as a chemical composition, by mass%: C: 0.100% to 0.350%; Si: 0.010% to 3.00%; Mn: 1.00% to 4.00%; sol. Al: 0.001% to 2.000%; Si+sol.Al: 1.00% or more; Ti: 0.010% to 0.380%; P: 0.100% or less; S: 0.0300% or less; N: 0.1000% or less; O: 0.0100% or less; and a remainder: Fe and impurities. Hereinafter, each element will be described in detail.

C: 0.100% to 0.350%

[0016] C is an element required to obtain desired strength. When a C content is less than 0.100%, it is difficult to obtain desired strength. Therefore, the C content is set to 0.100% or more. The C content is preferably 0.120% or more, or 0.150% or more.

[0017] On the other hand, when the C content is more than 0.350%, the transformation rate becomes slow, an MA (a mixed phase of fresh martensite and retained austenite) is likely to be generated, and it is difficult to obtain excellent isotropy in ductility and hole expansibility. Therefore, the C content is set to 0.350% or less. The C content is preferably 0.330% or less, or 0.310% or less.

Si: 0.010% to 3.00%

[0018] Si has a function of delaying precipitation of cementite. This function can increase the amount of untransformed austenite remaining, that is, the area ratio of retained austenite. In addition, the strength can be increased by maintaining a large amount of C dissolved in a hard phase and preventing cementite from coarsening. In addition, Si itself also has an effect of increasing the strength of the hot-rolled steel sheet according to solid solution strengthening. In addition, Si has a function of minimizing flaws in steel (minimizing the occurrence of defects such as blowholes in steel) by deoxidation. When the Si content is less than 0.010%, it is not possible to obtain the effect of the above function. Therefore, the Si content is set to 0.010% or more. The Si content is preferably 0.50% or more, 1.00% or more, 1.20% or more, or 1.50% or more.

[0019] On the other hand, when the Si content is more than 3.00%, this is not preferable because precipitation of cementite is significantly delayed and the amount of retained austenite becomes excessive. In addition, the surface properties and chemical convertibility of the hot-rolled steel sheet, as well as, ductility and weldability, significantly deteriorate, and the A_3 transformation point significantly rises. Accordingly, it is difficult to stably perform hot rolling. Therefore, the Si content is set to 3.00% or less. The Si content is preferably 2.70% or less or 2.50% or less.

Mn: 1.00 to 4.00%

[0020] Mn has a function of inhibiting ferrite transformation and increasing the strength of the hot-rolled steel sheet. When the Mn content is less than 1.00%, it is not possible to obtain desired strength. Therefore, the Mn content is set to 1.00% or more. The Mn content is preferably 1.50% or more, or 1.80% or more.

[0021] On the other hand, when the Mn content is more than 4.00%, isotropy in ductility and hole expansibility of the hot-rolled steel sheet deteriorate. Therefore, the Mn content is set to 4.00% or less. The Mn content is preferably 3.70% or less, 3.50% or less, 3.30% or less or 3.00% or less.

sol. Al: 0.001 to 2.000%

[0022] Like Si, sol. Al has a function minimizing flaws in the steel sheet by deoxydation of steel, inhibiting precipitation of cementite from austenite, and promoting generation of retained austenite. When the sol. Al content is less than 0.001%, it is not possible to obtain the effect of the above function. Therefore, the sol. Al content is set to 0.001% or more. The sol. Al content is preferably 0.010% or more.

[0023] On the other hand, when the sol. Al content is more than 2.000%, the above effect is maximized and it is not

economically preferable. In addition, the A_3 transformation point significantly rises, and it is difficult to stably perform hot rolling. Therefore, the sol. Al content is set to 2.000% or less. The sol. Al content is preferably 1.500% or less or 1.300% or less.

[0024] Here, in the present embodiment, sol. Al is acid-soluble Al, and indicates solid solution Al present in steel in a solid solution state.

Si+sol. Al: 1.00% or more

[0025] Si and sol. Al both have a function of delaying precipitation of cementite, and this function can increase the amount of untransformed austenite remaining, that is, the area ratio of retained austenite. When a total amount of Si and sol. Al is less than 1.00%, it is not possible to obtain the effect of the above function. Therefore, the total amount of Si and sol. Al is set to 1.00% or more. The total amount of Si and sol. Al is preferably 1.20% or more, or 1.50% or more.

[0026] Here, Si of "Si+sol. Al" indicates the content of Si by mass%, and sol. Al indicates the content of sol. Al by mass%.

Ti: 0.010 to 0.380%

[0027] Ti is an effective element for suppressing austenite recrystallization and grain growth between the stands of hot rolling. By suppressing recrystallization of austenite between the stands, strain can be further accumulated. As a result, the texture of the hot-rolled steel sheet can be preferably controlled. When the Ti content is less than 0.010%, it is not possible to obtain the effects. Therefore, the Ti content is set to 0.010% or more. The Ti content is preferably 0.050% or more, 0.070% or more, or 0.080% or more.

[0028] On the other hand, when the Ti content is more than 0.380%, inclusions attributed to TiN are generated, and the toughness of the hot-rolled steel sheet deteriorates. Therefore, the Ti content is set to 0.380% or less. The Ti content is preferably 0.320% or less, or 0.300% or less.

P: 0.100% or less

[0029] P is an element that is generally contained in steel as impurities, and has a function of increasing the strength of the hot-rolled steel sheet according to solid solution strengthening. Therefore, P may be actively contained. However, P is an element that easily segregates, and when the P content is more than 0.100%, hole expansibility and isotropy in ductility are significantly deteriorated due to grain boundary segregation. Therefore, the P content is set to 0.100% or less. The P content is preferably 0.030% or less.

[0030] Although it is not particularly necessary to specify the lower limit of the P content, 0.001 % is preferable in consideration of refining cost.

S: 0.0300% or less

[0031] S is an element that is contained in steel as impurities, and forms sulfide-based inclusions in steel, and deteriorates hole expansibility and isotropy in ductility of the hot-rolled steel sheet. When the S content is more than 0.0300%, hole expansibility and isotropy in ductility of the hot-rolled steel sheet significantly deteriorate. Therefore, the S content is set to 0.0300% or less. The S content is preferably 0.0050% or less.

[0032] Although it is not particularly necessary to specify the lower limit of the S content, 0.0001% is preferable in consideration of refining cost.

N: 0.1000% or less

[0033] N is an element that is contained in steel as impurities, and has a function of deteriorating hole expansibility and isotropy in ductility of the hot-rolled steel sheet. When the N content is more than 0.1000%, hole expansibility and isotropy in ductility of the hot-rolled steel sheet significantly deteriorate. Therefore, the N content is set to 0.1000% or less. The N content is preferably 0.0800% or less, or 0.0700% or less.

[0034] Although it is not particularly necessary to specify the lower limit of the N content, in order to promote precipitation of carbonitride, the N content is preferably 0.0010% or more and more preferably 0.0020% or more.

O: 0.0100% or less

[0035] When a large amount of O is contained in steel, a coarse oxide that acts as a starting point for fracture is formed, which causes brittle fracture or hydrogen-induced cracking. Therefore, the O content is 0.0100% or less. The O content is preferably 0.0080% or less or 0.0050% or less.

[0036] In order to disperse a large number of fine oxides during deoxydation of molten steel, the O content may be 0.0005% or more, or 0.0010% or more.

[0037] The remainder of the chemical composition of the hot-rolled steel sheet according to the present embodiment is composed of Fe and impurities. In the present embodiment, impurities are elements that are mixed in from ores or scrap as raw materials or a production environment or the like, or elements that are intentionally added in very small amounts, and have a meaning that they are allowable as long as they do not adversely affect the hot-rolled steel sheet according to the present embodiment.

[0038] The chemical composition of the hot-rolled steel sheet according to the present embodiment may contain the following elements as optional elements in addition to the above elements. The lower limit of the content when the following optional elements are not contained is 0%. Hereinafter, respective optional elements will be described in detail.

Nb: 0.005 to 0.100% and V: 0.005 to 0.500%

[0039] Like Ti, both Nb and V are elements that suppress austenite recrystallization and grain growth between the stands of hot rolling. Thus, one, two or more of these elements may be contained. In order to more reliably obtain the effect of the above function, it is preferable to set the Nb content to 0.005% or more, or the V content to 0.005% or more.

[0040] However, even when these elements are excessively contained, the effect of the above function is maximized and it is not economically preferable. Therefore, the Nb content is set to 0.100% or less, and the V content is set to 0.500% or less.

Cu: 0.01 to 2.00%, Cr: 0.01 to 2.00%, Mo: 0.01 to 1.00%, Ni: 0.02 to 2.00% and B: 0.0001 to 0.0100%

[0041] Cu, Cr, Mo, Ni and B all have a function of increasing the hardenability of the hot-rolled steel sheet. In addition, Cr and Ni have a function of stabilizing retained austenite, and Cu and Mo have a function of precipitating carbides in steel and increasing the strength of the hot-rolled steel sheet. In addition, when Cu is contained, Ni has a function of effectively reducing grain boundary cracks of a slab caused by Cu. Therefore, one, two or more of these elements may be contained.

[0042] As described above, Cu has a function of increasing the hardenability of the steel sheet and a function of precipitating as carbides in steel at a low temperature and increasing the strength of the hot-rolled steel sheet. In order to more reliably obtain the effect of the above function, the Cu content is preferably set to 0.01% or more.

[0043] However, when the Cu content is more than 2.00%, grain boundary cracks may occur in the slab. Therefore, the Cu content is set to 2.00% or less.

[0044] As described above, Cr has a function of increasing the hardenability of the steel sheet and a function of stabilizing retained austenite. In order to more reliably obtain the effect of the above function, the Cr content is preferably set to 0.01% or more.

[0045] However, when the Cr content is more than 2.00%, the chemical convertibility of the hot-rolled steel sheet is significantly lowered. Therefore, the Cr content is set to 2.00% or less.

[0046] As described above, Mo has a function of increasing the hardenability of the steel sheet and a function of precipitating carbides in steel and increasing the strength. In order to more reliably obtain the effect of the above function, the Mo content is preferably set to 0.01% or more.

[0047] However, even when the Mo content is more than 1.00%, the effect of the above function is maximized, and it is not economically preferable. Therefore, the Mo content is set to 1.00% or less.

[0048] As described above, Ni has a function of increasing the hardenability of the steel sheet. In addition, when Cu is contained, Ni has a function of effectively reducing grain boundary cracks of a slab caused by Cu. In order to more reliably obtain the effect of the above function, the Ni content is preferably set to 0.02% or more.

[0049] Since Ni is an expensive element, containing a large amount thereof is not economically preferable. Therefore, the Ni content is set to 2.00% or less.

[0050] As described above, B has a function of increasing the hardenability of the steel sheet. In order to more reliably obtain the effect of the function, the B content is preferably set to 0.0001 % or more.

[0051] However, when the B content is more than 0.0100%, since hole expansibility and isotropy in ductility of the hot-rolled steel sheet significantly deteriorate, the B content is set to 0.0100% or less.

Ca: 0.0005 to 0.0200%, Mg: 0.0005 to 0.0200%, REM: 0.0005 to 0.1000% and Bi: 0.0005 to 0.020%

[0052] Ca, Mg and REM all have a function of controlling the shape of the inclusion to a preferable shape and increasing the moldability of the hot-rolled steel sheet. In addition, Bi has a function of refining the solidified structure and increasing the moldability of the hot-rolled steel sheet. Therefore, one, two or more of these elements may be contained. In order to more reliably obtain the effect of the above function, it is preferable to contain 0.0005% or more of any one or more

of Ca, Mg, REM and Bi. However, when the Ca content or the Mg content is more than 0.0200% or the REM content is more than 0.1000%, inclusions are excessively generated in steel and thus hole expansibility and isotropy in ductility of the hot-rolled steel sheet may significantly deteriorate. In addition, even when the Bi content is more than 0.020%, the effect of the above function is maximized, and it is not economically preferable. Therefore, the Ca content and the Mg content are set to 0.0200% or less, the REM content is set to 0.1000% or less, and the Bi content is set to 0.020% or less. The Bi content is preferably 0.010% or less.

[0053] Here, REM refers to a total of 17 elements constituting of Sc, Y and lanthanides, and the REM content refers to a total amounts of these elements. In the case of lanthanides, they are industrially added in the form of misch metals.

One, two or more of Zr, Co, Zn and W: 0 to 1.00% in total and Sn: 0 to 0.050%

[0054] Regarding Zr, Co, Zn and W, the inventors confirmed that, even when a total amount of 1.00% or less of these elements is contained, the effects of the hot-rolled steel sheet according to the present embodiment are not impaired. Therefore, a total amount of 1.00% or less of one, two or more of Zr, Co, Zn and W may be contained.

[0055] In addition, the inventors confirmed that, even when a small amount of Sn is contained, the effects of the hot-rolled steel sheet according to the present embodiment are not impaired, but flaws during hot rolling may occur so that the Sn content is 0.050% or less.

[0056] The chemical composition of the above hot-rolled steel sheet may be measured by a general analysis method. For example, inductively coupled plasma-atomic emission spectrometry (ICP-AES) may be used for measurement. Here, sol. Al may be measured through ICP-AES using a filtrate after thermal decomposition of a sample with an acid. C and S may be measured using a combustion-infrared absorption method, N may be measured using an inert gas fusion-thermal conductivity method, and O may be measured using an inert gas fusion-non-dispersive infrared absorption method.

Microstructure of Hot-Rolled Steel Sheet

[0057] Next, a microstructure of the hot-rolled steel sheet according to the present embodiment will be described.

[0058] In the hot-rolled steel sheet according to the present embodiment, a microstructure in a region from a depth of 1/8 of a sheet thickness from the surface to a depth of 3/8 of the sheet thickness from the surface comprises, by area%, retained austenite: 10% to 20%, fresh martensite: 10% or less, and bainite: 70% to 90%, in a texture of a region from the surface to the 1/8 thickness depth from the surface, pole densities of {001}<110>, {111}<110>, and {112}<110> orientation groups are 2.0 to 8.0, in a texture of a region from the depth of 1/8 of the sheet thickness from the surface to a depth of 1/2 of the sheet thickness from the surface, a pole density of a {110}<112> orientation is 2.0 to 4.0.

[0059] In the present embodiment, area% of retained austenite, fresh martensite and bainite at a depth position of 1/4 of the sheet thickness from the surface (in the region from the depth of 1/8 of the sheet thickness from the surface to the depth of 3/8 of the sheet thickness from the surface) is specified. The reason for this is that the microstructure at this position represents a typical microstructure of the hot-rolled steel sheet.

Retained Austenite: 10% to 20%

[0060] Retained austenite is a structure that improves hole expansibility and isotropy in ductility of the hot-rolled steel sheet. When the area ratio of retained austenite is less than 10%, it is not possible to obtain desired hole expansibility and isotropy in ductility. Therefore, the area ratio of retained austenite is set to 10% or more. The area ratio of retained austenite is preferably 12% or more, or 13% or more.

[0061] On the other hand, when the area ratio of retained austenite is more than 20%, it is not possible to obtain desired strength. Therefore, the area ratio of retained austenite is set to 20% or less. The area ratio of retained austenite is preferably 18% or less, or 17% or less.

Fresh Martensite: 10% or less

[0062] Since fresh martensite is a hard structure, it contributes to improving the strength of the hot-rolled steel sheet. However, fresh martensite is structure that is poor in hole expansibility and isotropy in ductility. When the area ratio of fresh martensite is more than 10%, it is not possible to obtain desired hole expansibility and isotropy in ductility. Therefore, the area ratio of fresh martensite is set to 10% or less. The area ratio of fresh martensite is preferably 8% or less, 6% or less, 4% or less, or 2% or less. The area ratio of fresh martensite may be 0%.

Bainite: 70% to 90%

[0063] Bainite is a structure that improves the strength and isotropy in ductility of the hot-rolled steel sheet. When the area ratio of bainite is less than 70%, it is not possible to obtain desired strength. Therefore, the area ratio of bainite is set to 70% or more. The area ratio of bainite is preferably 73% or more, 75% or more, or 77% or more.

[0064] On the other hand, when the area ratio of bainite is more than 90%, strength becomes too high and it is not possible to obtain desired hole expansibility. Therefore, the area ratio of bainite is set to 90% or less. The area ratio of bainite is preferably less than 90%, 88% or less, or 85% or less.

[0065] Among the above structures, the area ratio of structures other than retained austenite is measured by the following method.

[0066] A test piece is taken from the hot-rolled steel sheet so that the microstructure of the sheet thickness cross section parallel to the rolling direction at a depth of 1/4 of the sheet thickness from the surface (an area from the surface to a depth of 1/8 of the sheet thickness to from the surface to a depth of 3/8 of the sheet thickness) can be observed. Next, the sheet thickness cross section is polished, the polished surface is then subjected to nital corrosion, and a 30 $\mu\text{m} \times 30 \mu\text{m}$ area is subjected to structure observation using an optical microscope and a scanning electron microscope (SEM). Observation areas are at least three areas. Image analysis is performed on the structure image obtained by the structure observation, and the area ratio of bainite is obtained. Then, Le Pera corrosion is performed on the same observation position, structure observation is then performed using an optical microscope and a scanning electron microscope, image analysis is performed on the obtained structure image, and thereby the area ratio of fresh martensite is obtained.

[0067] In the above structure observation, each structure is identified by the following method.

[0068] Fresh martensite is a structure having a high dislocation density and substructures such as blocks and packets within the grains so that it is possible to distinguish it from other microstructures according to electron channeling contrast images using a scanning electron microscope.

[0069] A structure that is an aggregate of lath-shaped crystal grains, and is not fresh martensite among structures that do not contain Fe-based carbides with a major axis of 20 nm or more inside the structure or a structure which contains Fe-based carbides with a major axis of 20 nm or more inside the structure and in which the Fe-based carbides have a single variant, that is, Fe-based carbides extending in the same direction, is regarded as bainite. Here, Fe-based carbides elongated in the same direction are Fe-based carbides with a difference of 5° or less in the elongation direction.

[0070] The area ratio of retained austenite is measured by the following method.

[0071] In the present embodiment, the area ratio of retained austenite is measured by X-ray diffraction. First, in the sheet thickness cross section parallel to the rolling direction of the hot-rolled steel sheet, at a depth of 1/4 of the sheet thickness from the surface (an area from the surface to a depth of 1/8 of the sheet thickness to from the surface to a depth of 3/8 of the sheet thickness), using Co-K α rays, an integrated intensity of a total of 6 peaks of $\alpha(110)$, $\alpha(200)$, $\alpha(211)$, $\gamma(111)$, $\gamma(200)$, and $\gamma(220)$ is obtained, and the volume ratio of retained austenite is calculated using the intensity average method. This volume ratio of retained austenite is regarded as the area ratio of retained austenite.

[0072] Pole Densities of {001}<110>, {111}<110>, and {112}<110> Orientation Group in Texture of Region from Surface to Depth of 1/8 of Sheet Thickness from Surface: 2.0 to 8.0

[0073] When the pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups in the texture of the region (hereinafter, sometimes referred to as a surface layer region) from the surface to the depth of 1/8 of the sheet thickness from the surface are less than 2.0, isotropy in ductility and hole expansibility of the hot-rolled steel sheet deteriorate. Therefore, the pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups in the texture of the surface layer region are set to 2.0 or more. The pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups in the texture of the surface layer region are preferably 2.2 or more, 2.5 or more, or 2.7 or more.

[0074] When the pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups in the texture of the region (hereinafter, sometimes referred to as a surface layer region) from the surface to the depth of 1/8 of the sheet thickness from the surface are more than 8.0, isotropy in ductility and hole expansibility of the hot-rolled steel sheet deteriorate. Therefore, the pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups in the texture of the surface layer region are set to 8.0 or less. The pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups in the texture of the surface layer region are preferably 7.5 or less, or 7.0 or less.

[0075] Pole Density of {110}<112> Orientation in Texture of Region from Depth of 1/8 of Sheet Thickness from Surface to Depth of 1/2 of Sheet Thickness from Surface: 2.0 to 4.0

[0076] The pole density of the {110}<112> orientation in the texture of the region (hereinafter, sometimes referred to as an internal region) from the depth of 1/8 of the sheet thickness from the surface to the depth of 1/2 of the sheet thickness from the surface is more than 4.0, isotropy in ductility and hole expansibility of the hot-rolled steel sheet deteriorate. Therefore, the pole density of the {110}<112> orientation in the texture of the internal region is set to 4.0 or less. The pole density of the {110}<112> orientation in the texture of the internal region is preferably 3.6 or less, 3.2 or less, or 3.0 or less.

[0077] The pole density of the {110}<112> orientation in the texture of the internal region is set to 2.0 or more from the viewpoint of suppressing the deterioration of strength. The pole density of the { 110} <112> orientation in the texture of the internal region is preferably 2.3 or more, or 2.5 or more.

[0078] For the pole densities, a device in which a scanning electron microscope and an EBSD analyzer are combined and OIM analysis (registered trademark) manufactured by AMETEK Inc. are used. From an orientation distribution function (ODF) that is calculated by using orientation data measured by an electron backscattering diffraction (EBSD) method and a spherical harmonic function and displays a three-dimensional texture, the pole densities of the {001}<110>, {111}<110>, and { 112}<110> orientation groups in the texture of the surface layer region and the pole density of the { 110}<112> in the texture of the internal region are obtained.

[0079] A measurement range is set to, for the surface layer region, the region from the surface to the depth of 1/8 of the sheet thickness from the surface and for the internal region, the region from the depth of 1/8 of the sheet thickness from the surface to the depth of 1/2 of the sheet thickness from the surface. Measurement pitches are set to 5 μm /step.

[0080] It should be noted that {hkl} indicates a crystal plane parallel to a rolled surface and <uvw> indicates a crystal direction parallel to the rolling direction. That is, {hkl}<uvw> indicates a crystal in which {hkl} is oriented in a sheet surface normal direction and <uvw> is oriented in the rolling direction.

[0081] The rolling direction of the hot-rolled steel sheet can be determined by the following method.

[0082] First, a test piece is collected so that a sheet thickness cross section of the hot-rolled steel sheet can be observed. The sheet thickness cross section of the collected test piece is finished by mirror polishing and then observed using an optical microscope. An observation range is set to an overall thickness of the sheet thickness, and a region with dark brightness is determined to be an inclusion. Among inclusions, in inclusions having a major axis length of 40 μm or more, a direction parallel to a direction in which the inclusion extends is determined to be the rolling direction.

Mechanical Properties

[0083] The hot-rolled steel sheet according to the present embodiment has a tensile (maximum) strength of 980 MPa or more. When the tensile strength is set to 980 MPa or more, it is possible to contribute to weight reduction of the vehicle body. More preferably, the tensile strength is 1,180 MPa or more. It is not particularly necessary to limit the upper limit, but may be 1,470 MPa, 1,300 MPa or less, or 1,200 MPa or less.

[0084] The difference between the total elongation in the C direction and the total elongation in the L direction ((total elongation in the L direction - total elongation in the C direction) / total elongation in the C direction), which is an index of isotropy in ductility, is preferably $\pm 3.0\%$ or less.

[0085] The hole expansion ratio, which is an index of hole expansibility, is preferably 40% or more.

[0086] The tensile strength TS and the total elongation EL are measured according to JIS Z 2241: 2011 using No. 5 test piece of JIS Z 2241: 2011. The position of the tensile test piece that is taken out may be a part of 1/4 from the end in the sheet width direction, and the direction perpendicular to the rolling direction (the C direction) may be a longitudinal direction. Regarding the total elongation EL, the total elongation in the L direction is measured by also performing a tensile test on a tensile test piece whose longitudinal direction is parallel to the rolling direction (the L direction).

[0087] The hole expansion ratio λ is measured according to JIS Z 2256: 2010 using No. 5 test piece of JIS Z 2241: 2011. The position of the hole expansion test piece that is taken out may be a part of 1/4 from the end of the hot-rolled steel sheet in the sheet width direction.

Sheet Thickness

[0088] The sheet thickness of the hot-rolled steel sheet according to the present embodiment is not particularly limited, but may be 1.2 to 8.0 mm. When the sheet thickness of the hot-rolled steel sheet is set to 1.2 mm or more, it is possible to easily secure the rolling completion temperature, it is possible to reduce the rolling load, and it is possible to easily perform hot rolling. Therefore, the sheet thickness of the hot-rolled steel sheet according to the present embodiment may be 1.2 mm or more, and is preferably 1.4 mm or more. In addition, when the sheet thickness is set to 8.0 mm or less, the texture can be easily controlled, and it is possible to easily obtain the above texture. Therefore, the sheet thickness may be 8.0 mm or less, and is preferably 6.0 mm or less.

Plating Layer

[0089] The hot-rolled steel sheet according to the present embodiment having the chemical composition and micro-structure described above may have a plating layer on the surface in order to improve corrosion resistance, and may be used as a surface-treated steel sheet. The plating layer may be an electroplating layer or a melt plating layer. Examples of electroplating layers include electrogalvanizing and electro Zn-Ni alloy plating. Examples of melt plating layers include melt galvanizing, alloyed melt galvanizing, melt aluminum plating, melt Zn-Al alloy plating, melt Zn-Al-Mg alloy plating,

and melt Zn-Al-Mg-Si alloy plating. The amount of plating adhered is not particularly limited, and may be the same as in the related art. In addition, after plating, an appropriate chemical conversion treatment (for example, applying a silicate-based chromium-free chemical conversion treatment solution and drying) is performed, and it is possible to further improve corrosion resistance.

[0090] Next, a preferred manufacturing method of the hot-rolled steel sheet according to the present embodiment will be described. The preferred manufacturing method of the hot-rolled steel sheet according to the present embodiment includes the following steps (a) to (d). Unless otherwise specified, a temperature in the following description refers to a surface temperature of the steel sheet.

(a) A heating step of heating a slab having the above-described chemical composition to a temperature range of 1,100°C or higher and lower than 1,350°C.

(b) A finish rolling step of performing finish rolling on the heated slab using a rolling mill having a plurality of stands, in which the following conditions (1) to (V) are satisfied.

(I) A finish rolling start temperature is set to 850°C or higher.

(II) In each of the last four stands among the plurality of stands, rolling is performed so that σ represented by Expression (1) becomes 40 to 80.

$$\sigma = \exp(0.753 + 3000/T) \times \varepsilon^{0.21} \times \varepsilon'^{0.13} \dots (1)$$

Here, T is a temperature (°C) immediately before entering each stand, ε is an equivalent plastic strain, and ε' is a strain rate.

(III) Interpass times between the last four stands are set to 0.1 to 10.0 seconds.

(IV) A cumulative rolling reduction of the last four stands is set to 60% or larger.

(V) A finishing temperature is set to 850°C to 1,000°C.

(c) A cooling step of performing air cooling for 2.0 to 4.0 seconds after completion of finish rolling, and then, performing cooling to a temperature range of 450°C to 550°C at an average cooling rate of 100 °C/s or faster.

(d) A coiling step of performing coiling after the cooling.

[0091] Hereinafter, each step will be described.

(a) Heating Step

[0092] In the heating step, it is preferable to heat the slab having the above-mentioned chemical composition to a temperature range of 1,100°C or higher and lower than 1,350°C. A method of manufacturing the slab does not need to be particularly limited, and a commonly used method can be applied in which molten steel having the above-described chemical composition is melted in a converter or the like and is cast into a slab by a casting method such as continuous casting. In addition, an ingot-making and blooming method may be used.

[0093] In the slab, most of carbonitride-forming elements such as Ti are present in the slab as coarse carbonitrides in a non-uniform distribution. The coarse precipitates (carbonitrides) present in a non-uniform distribution deteriorate various properties (for example, tensile strength, ductility, and hole expansibility) of the hot-rolled steel sheet. Therefore, the slab before hot rolling is heated at the desired temperature range to solid-solubilize the coarse precipitates. In order to sufficiently solid-solubilize these coarse precipitates before hot rolling, a heating temperature of the slab is preferably set to 1,100°C or higher. However, an excessively high heating temperature for the slab causes the generation of surface defects and a decrease in yield due to scale removal. Therefore, the heating temperature of the steel material is preferably set to lower than 1,350°C.

[0094] The slab is heated to the temperature range of 1,100°C or higher and lower than 1,350°C and held for a predetermined time. However, when a holding time is longer than 4,800 seconds, the amount of scale generated increases. As a result, a rolled-in scale or the like is likely to occur in the subsequent finish rolling step, and there are cases where surface quality of the hot-rolled steel sheet deteriorates. Therefore, the holding time in the temperature range of 1,100°C or higher and lower than 1,350°C is preferably set to 4,800 seconds or shorter.

Rough Rolling Step

[0095] Rough rolling may be performed on the slab between the heating step and the finish rolling step. Conditions of the rough rolling are not particularly limited as long as desired sheet bar dimensions can be obtained.

(b) Finish Rolling Step

[0096] In the finish rolling step, the heated slab is subjected to finish rolling using the rolling mill having the plurality of stands. Here, it is preferable to satisfy the conditions (1) to (V) to be described below.

[0097] It is preferable to perform descaling before the finish rolling or during rolling between the rolling stands during the finish rolling.

(I) Finish Rolling Start Temperature: 850°C or Higher

[0098] The finish rolling start temperature (an entry-side temperature of a first pass of the finish rolling) is preferably set to 850°C or higher. When the finish rolling start temperature is lower than 850°C, rolling in some of the plurality of rolling stands (particularly the stands in the first half) is performed at a temperature in a ferrite/austenite dual phase region. As a result, a worked structure remains after the finish rolling, and there are cases where the strength and ductility of the hot-rolled steel sheet deteriorate. Therefore, the finish rolling start temperature is preferably set to 850°C or higher.

[0099] The finish rolling start temperature may be set to 1,100°C or lower in order to suppress coarsening of austenite.

(II) In Each of Last Four Stands, σ Represented by Expression (1): 40 to 80

[0100]

$$\sigma = \exp(0.753 + 3000/T) \cdot \varepsilon^{0.21} \cdot \varepsilon'^{0.13} \dots (1)$$

[0101] Here, T is the temperature (°C) immediately before entering each stand (that is, the entry-side temperature), ε is the equivalent plastic strain, and ε' is the strain rate.

[0102] The fact that σ in each of the last four stands is 40 to 80 can be rephrased as follows: σ of the fourth stand from the last stand, σ of the third stand from the last stand, σ of the second stand from the last stand, and σ of the last stand are all 40 to 80.

[0103] When there is even one stand in which σ is less than 40, there are cases where strain necessary for the development of the texture in the surface layer region is not suitably applied in each of the last four stands. As a result, there are cases where in the texture of the region from the surface to the depth of 1/8 of the sheet thickness from the surface, the pole densities of the {001}<110>, {111}<110>, and {112}<110> orientation groups cannot be preferably controlled. In addition, there are cases where the texture in the internal region cannot be preferably controlled. Therefore, σ in each of the last four stands is preferably set to 40 or more.

[0104] In addition, when there is even one stand in which σ is more than 80, there are cases where the above texture does not develop and the structure becomes random due to dynamic recrystallization. As a result, there are cases where isotropy in ductility and hole expansibility of the hot-rolled steel sheet deteriorate. Therefore, σ in each of the last four stands is preferably set to 80 or less.

[0105] In addition, ε , which is the equivalent plastic strain, can be obtained by $\varepsilon = (2/\sqrt{3}) \times (h/H)$ when an entry-side sheet thickness is represented by h and an exit-side sheet thickness is represented by H. In addition, the strain rate ε' can be obtained by $\varepsilon' = \varepsilon/t$ when a rolling time is t (s).

[0106] In addition, the rolling time t refers to a time during which strain is applied to the steel sheet when the steel sheet and the rolling roll come into contact with each other.

(III) Interpass Times between Last Four Stands: 0.1 to 10.0 Seconds

[0107] When there is even one pass in which the interpass time is longer than 10.0 seconds between the last four stands, recovery and recrystallization between the passes progresses. As a result, it becomes difficult to accumulate strain, and there are cases where a desired texture in the surface layer region and the internal region cannot be obtained. Therefore, the interpass times between the last four stands are preferably set to 10.0 seconds or shorter.

[0108] Since the interpass times between the last four stands are preferably short, but a reduction in the interpass times are limited in terms of an installation space of each stand and a rolling rate, the interpass times between the last four stands are preferably set to 0.1 seconds or longer.

[0109] The interpass times between the last four stands are 0.1 to 10.0 seconds can be rephrased as follows: interpass time between the fourth stand from the last stand and the third stand from the last stand, the interpass time between the third stand from the last stand and the second stand from the last stand, and the interpass time between the second stand from the last stand and the last stand are all 0.1 to 10.0 seconds.

(IV) Cumulative Rolling Reduction of Last Four Stands: 60% or Larger

[0110] When the cumulative rolling reduction of the last four stands is smaller than 60%, there are cases where a dislocation density introduced into unrecrystallized austenite decreases. When the dislocation density introduced into unrecrystallized austenite decreases, it becomes difficult to obtain a desired texture, and there are cases where hole expansibility and isotropy in ductility of the hot-rolled steel sheet deteriorate. Therefore, the cumulative rolling reduction of the last four stands is preferably set to 60% or larger.

[0111] When the cumulative rolling reduction of the last four stands is larger than 97%, there are cases where a shape of the hot-rolled steel sheet deteriorates. Therefore, the cumulative rolling reduction of the last four stands may be set to 97% or smaller.

[0112] The cumulative rolling reduction of the last four stands can be represented by $\{1 - (t_1/t_0)\} \times 100$ (%) when an inlet sheet thickness of the fourth stand from the last stand is represented by t_0 and an outlet sheet thickness of the last stand is represented by t_1 .

(V) Finishing temperature: 850°C to 1,000°C

[0113] When the finish rolling finishing temperature (exit-side temperature of the last stand) is lower than 850°C, the rolling is performed at a temperature in the ferrite/austenite dual phase region. Thereby, there are cases where the worked structure remains after the rolling and strength and isotropy in ductility of the hot-rolled steel sheet deteriorate. Therefore, the finishing temperature is preferably set to 850°C or higher.

[0114] In addition, in the slab having the chemical composition according to the present embodiment, an unrecrystallized austenite region is a temperature range of approximately 1,000°C or lower. Therefore, when the finishing temperature is higher than 1,000°C, austenite grains grow, and a grain length of martensite in the hot-rolled steel sheet obtained after the cooling increases. As a result, it becomes difficult to obtain a desired texture, and there are cases where strength and isotropy in ductility of the hot-rolled steel sheet deteriorate. Therefore, the finishing temperature is preferably set to 1,000°C or lower.

(c) Cooling Step

[0115] In the cooling step, it is preferable that air cooling is performed for 2.0 to 4.0 seconds after completion of the finish rolling, and then, cooling is performed to a temperature range of 450°C to 550°C at an average cooling rate of 100 °C/s or faster.

Air Cooling Time: 2.0 to 4.0 seconds

[0116] After completion of the finish rolling, it is preferable that air cooling is performed for 2.0 to 4.0 seconds. When air cooling time is shorter than 2.0 seconds or longer than 4.0 seconds, there are cases where a desired amount of bainite cannot be obtained. Therefore, air cooling is preferably performed for 2.0 to 4.0 seconds.

[0117] Here, air cooling in the present embodiment means a cooling at an average cooling rate of slower than 10 °C/s.

[0118] In the present embodiment, it is preferable that cooling equipment is installed at a rear stage of finish rolling equipment, and the cooling is performed while the steel sheet after the finish rolling passes through the cooling equipment after the above air cooling. The cooling mentioned here does not include the above air cooling.

[0119] The cooling equipment is preferably equipment that can cool the steel sheet at an average cooling rate of 100 °C/s or faster. Examples of the cooling equipment include water cooling equipment using water as a cooling medium.

[0120] The average cooling rate in the cooling step is a value obtained by dividing a temperature drop width of the steel sheet from when the cooling is started to when the cooling is ended by a time required from when the cooling is started to when the cooling is ended. When the cooling is started refers to a time when the steel sheet is introduced into the cooling equipment, and when the cooling is ended refers to a time when the steel sheet is taken out of the cooling equipment.

[0121] Examples of the cooling equipment include equipment having no intermediate air cooling section and equipment having at least one intermediate air cooling section. In the present embodiment, any cooling equipment may be used. Even in a case where cooling equipment having an air cooling section is used, the average cooling rate from the start of cooling to the end of cooling may be 100 °C/s or faster.

[0122] Average Cooling Rate from Finishing Temperature of Air Cooling to Temperature Range of 450°C to 550°C: 100 °C/s or Faster

[0123] When the average cooling rate from finishing temperature of air cooling to the temperature range of 450°C to 550°C is slower than 100 °C/s, bainite or ferrite is likely to be formed, and there are cases where a desired amount of bainite cannot be obtained. Therefore, the average cooling rate from finishing temperature of air cooling to the temperature

range of 450°C to 550°C is preferably set to 100 °C/s or faster.

(d) Coiling Step

[0124] In the coiling step, the steel sheet cooled to a temperature range of 450°C 550°C is preferably coiled. Since the steel sheet is coiled immediately after the cooling, a coiling temperature is almost equal to the cooling stop temperature. When the coiling temperature is lower than 450°C, there are cases where a desired amount of bainite cannot be obtained, thereby isotropy in ductility and hole expansibility deteriorate. In addition, when the coiling temperature is higher than 550°C, there are cases where a large amount of ferrite and pearlite is generated, thereby a desired strength cannot be obtained. Therefore, the coiling temperature is preferably set to a temperature range of 450°C to 550°C.

[0125] Air cooling may be performed after the coiling. After the coiling, the hot-rolled steel sheet may be subjected to temper rolling according to a conventional method, or subjected to pickling to remove the scale formed on the surface. Alternatively, a plating treatment such as aluminum plating, aluminum-zinc plating, aluminum-silicon plating, hot-dip galvanizing, electrogalvanizing, and hot-dip galvannealing, or a chemical conversion treatment may be performed.

[0126] The hot-rolled steel sheet according to the present embodiment can be stably manufactured by the preferred manufacturing method described above.

[Examples]

[0127] Next, examples of the present invention will be described. Conditions in the examples are one example of conditions adopted to confirm the feasibility and effects of the present invention, and the present invention is not limited to this example of conditions. The present invention may adopt various conditions to achieve the object of the present invention without departing from the scope of the present invention.

[0128] Molten steels having the chemical compositions shown in Table 1 were melted in a converter and slabs were obtained by a continuous casting method. Next, these slabs were heated under the conditions shown in Tables 2A and 2B, subjected to rough rolling, and then subjected to finish rolling under the conditions shown in Tables 2A and 2B. After the finish rolling was completed, the slabs were cooled and coiled under the conditions shown in Tables 3A and 3B to obtain hot-rolled steel sheets having the sheet thicknesses shown in Tables 3A and 3B.

[0129] In the heating step, holding times at the heating temperatures shown in Tables 2A and 2B were set to 4,800 seconds or shorter.

[0130] In addition, as cooling (excluding air cooling) after the finish rolling, water cooling was performed in which the steel sheet was passed through water cooling equipment having no intermediate air cooling section. An average cooling rate in Tables 3A and 3B is a value obtained by dividing a temperature drop width of the steel sheet from when the steel sheet was introduced into the water cooling equipment to when the steel sheet was taken out of the water cooling equipment by a time required for the steel sheet to be passed through the water cooling equipment.

[0131] A test piece was collected from the obtained hot-rolled steel sheet, an area ratio of each structure, pole densities of textures, a tensile strength, total elongations in the C direction and the L direction, and a hole expansion ratio were measured by the above-described methods.

[0132] The obtained results are shown in Tables 4A and 4B.

[0133] In a case where an obtained tensile strength was 980 MPa or more, the hot-rolled steel sheet was determined to be acceptable as having high strength. On the other hand, in a case where the obtained tensile strength was less than 980 MPa, the hot-rolled steel sheet was determined to be unacceptable as not having high strength.

[0134] In a case where an obtained difference between the total elongation in the C direction and the total elongation in the L direction was $\pm 3.0\%$ or less, the hot-rolled steel sheet was determined to be acceptable as having excellent isotropy in ductility. On the other hand, in a case where an obtained difference between the total elongation in the C direction and the total elongation in the L direction was more than $\pm 3.0\%$, the hot-rolled steel sheet was determined to be unacceptable as not having excellent isotropy in ductility.

[0135] In a case where an obtained hole expansion ratio was 40% or more, the hot-rolled steel sheet was determined to be acceptable as having excellent hole expansibility. On the other hand, in a case where an obtained hole expansion ratio was less than 40%, the hot-rolled steel sheet was determined to be unacceptable as not having excellent hole expansibility.

[Table 1]

Kind of steel	Chemical composition (mass%), remainder being Fe and impurities											Note
	C	Si	Mn	sol. Al	Si+ sol. Al	Ti	P	S	N	O	Others	
A	0.180	0.95	1.50	0.018	1.10	0.050	0.023	0.0150	0.0030	0.0016		Present Invention Steel
B	0.200	2.55	3.60	1.100	2.55	0.200	0.010	0.0020	0.0030	0.0016	Nb: 0.030, V: 0.030	Present Invention Steel
C	0.210	1.50	1.80	0.040	2.10	0.070	0.020	0.0040	0.0030	0.0016	Nb: 0.050. Cu: 0.04	Present Invention Steel
D	0.190	1.20	2.00	0.600	1.50	0.090	0.010	0.0030	0.0030	0.0016	Nb: 0.020, Cr: 0.05	Present Invention Steel
E	0.310	2.00	1.60	0.080	1.80	0.080	0.020	0.0120	0.0030	0.0016	Nb: 0.010. Mo: 0.10, B: 0.0030	Present Invention Steel
F	0.280	2.40	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016	Nb: 0.010, Ni: 1.20, Ca: 0.0040	Present Invention Steel
G	0.240	1.30	2.50	0.900	1.90	0.190	0.014	0.0060	0.0030	0.0016	V: 0.200, Mg: 0.0050. REM: 0.0500. Bi: 0.010	Present Invention Steel
H	0.120	3.40	2.50	0.900	2.20	0.190	0.016	0.0070	0.0030	0.0016		Comparative Steel
I	0.370	2.30	3.10	0.070	2.00	0.230	0.014	0.0090	0.0030	0.0016		Comparative Steel
J	0.190	1.10	1.50	0.018	1.10	0.001	0.023	0.0150	0.0030	0.0016		Comparative Steel
K	0.100	2.40	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
L	0.350	2.40	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
M	0.280	0.01	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
O	0.280	3.00	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
P	0.280	2.40	4.00	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
Q	0.280	2.40	1.10	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
R	0.280	2.40	2.60	0.001	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
S	0.280	2.40	2.60	2.000	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
T	0.280	2.40	2.60	0.050	1.40	0.010	0.020	0.0130	0.0030	0.0016		Present Invention Steel
U	0.280	2.40	2.60	0.050	1.40	0.380	0.020	0.0130	0.0030	0.0016		Present Invention Steel
V	0.280	2.40	2.60	0.050	1.40	0.160	0.100	0.0130	0.0030	0.0016		Present Invention Steel
W	0.280	2.40	2.60	0.050	1.40	0.160	0.020	0.0300	0.0030	0.0016		Present Invention Steel
X	0.280	2.40	2.60	1.700	1.40	0.160	0.020	0.0130	0.0030	0.0016		Present Invention Steel
Y	0.280	2.40	2.60	0.050	1.40	0.160	0.020	0.0130	0.1000	0.0016		Present Invention Steel

(continued)

Kind of steel	Chemical composition (mass%), remainder being Fe and impurities										Note	
	C	Si	Mn	sol. Al	Si+ sol. Al	Ti	P	S	N	O		Others
Z	0.280	2.40	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0100		Present Invention Steel
AA	<u>0.080</u>	2.40	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Comparative Steel
AB	0.280	<u>0.006</u>	2.60	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Comparative Steel
AC	0.280	2.40	<u>0.80</u>	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Comparative Steel
AD	0.280	2.40	<u>4.30</u>	0.050	1.40	0.160	0.020	0.0130	0.0030	0.0016		Comparative Steel
AE	0.280	2.40	2.60	0.050	<u>4.20</u>	0.160	0.020	0.0130	0.0030	0.0016		Comparative Steel
The underlined value indicates outside of the range of the present invention.												

[Table 2A]

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling									Note	
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand-	(II) σ of third stand from last stand-	(II) σ of second stand from last stand-	(II) σ of last stand-	(III) Intei σ pass time between fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %		(V) Finishing temperature °C
1	A	1187	893	75	62	43	40	6.0	3.0	1.2	65	889	Present Invention Example
2	A	1143	878	78	59	59	60	7.0	2.0	0.7	65	828	Present Invention Example
3	A	1100	1040	56	43	42	59	3.0	2.0	0.9	61	872	Present Invention Example
4	A	1283	857	52	60	55	45	2.0	2.0	0.7	83	908	Present Invention Example
5	A	1254	878	72	46	41	35	7.0	7.0	0.2	56	918	Comparative Example
6	B	1308	882	55	43	43	51	8.0	1.0	0.7	78	868	Present Invention Example
7	B	1160	1050	77	54	42	42	5.0	6.0	0.7	68	904	Present Invention Example
8	B	1217	1028	67	69	58	43	11.0	8.0	5.0	75	837	Comparative Example

(continued)

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling									Note	
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand-	(II) σ of third stand from last stand-	(II) σ of second stand from last stand-	(II) σ of last stand-	(III) Intei σ between fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %		(V) Finishing temperature °C
9	C	1198	982	66	41	60	58	8.0	5.0	4.0	87	800	Present Invention Example
10	C	1189	1055	54	66	40	54	7.0	6.0	1.0	87	857	Present Invention Example
11	C	1176	930	78	48	65	48	3.0	2.0	0.4	88	816	Comparative Example
12	D	1202	992	53	62	65	60	4.0	3.0	0.9	95	926	Present Invention Example
13	D	1232	861	70	53	47	55	4.0	6.0	0.2	70	915	Present Invention Example
14	D	1128	963	71	44	45	89	6.0	5.0	0.9	84	896	Comparative Example
15	E	1287	861	54	58	61	40	7.0	7.0	3.0	90	845	Present Invention Example
16	E	1285	897	69	46	48	41	7.0	7.0	0.3	80	947	Present Invention Example

(continued)

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling										Note
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand-	(II) σ of third stand from last stand-	(II) σ of second stand from last stand-	(II) σ of last stand-	(III) σ of fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %	(V) Finishing temperature °C	
17	E	1212	954	56	41	56	46	8.0	3.0	0.1	87	876	Comparative Example
18	F	1105	1079	76	47	64	42	5.0	6.0	0.9	62	827	Present Invention Example
19	F	1176	1016	62	41	61	44	5.0	3.0	0.5	93	895	Present Invention Example
20	F	1135	<u>840</u>	74	60	50	<u>36</u>	5.0	6.0	4.0	<u>55</u>	<u>780</u>	Comparative Example
21	C	1204	1010	78	54	59	53	5.0	5.0	0.4	82	917	Present Invention Example
22	C	1328	1050	76	58	49	52	3.0	1.0	0.5	63	833	Present Invention Example
23	C	1327	900	<u>85</u>	70	60	70	3.0	2.0	0.9	95	913	Comparative Example
24	<u>H</u>	1199	1071	65	47	53	<u>35</u>	8.0	5.0	1.0	84	940	Comparative Example
25	<u>I</u>	1184	949	78	54	40	42	2.0	5.0	0.3	75	931	Comparative Example

(continued)

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling									Note	
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand-	(II) σ of third stand from last stand-	(II) σ of second stand from last stand-	(II) σ of last stand-	(III) Intei σ between fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %		(V) Finishing temperature °C
26	J	1256	980	78	47	43	41	6.0	5.0	0.3	72	901	Comparative Example

The underlined value indicates undesirable manufacturing conditions.

[Table 2B]

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling										Note
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand -	(II) σ of third stand from last stand -	(II) σ of second stand from last stand -	(II) σ of last stand -	(III) Inter-pass time between fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %	(V) Finishing temperature °C	
27	K	1296	1005	53	79	75	41	2.0	3.0	6.0	95	837	Present Invention Example
28	L	1146	949	53	73	46	70	4.0	4.0	4.0	87	868	Present Invention Example
29	M	1315	982	79	55	43	41	5.0	4.0	5.0	70	834	Present Invention Example
30	O	1111	900	46	75	78	65	5.0	2.0	4.0	93	890	Present Invention Example
31	P	1306	1011	49	77	51	77	6.0	4.0	4.0	81	927	Present Invention Example
32	Q	1198	857	46	61	66	60	4.0	7.0	6.0	63	922	Present Invention Example
33	R	1145	916	56	63	63	42	4.0	7.0	6.0	73	852	Present Invention Example
34	S	1310	1026	49	60	51	68	2.0	6.0	2.0	63	894	Present Invention Example

(continued)

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling										Note
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand -	(II) σ of third stand from last stand -	(II) σ of second stand from last stand -	(II) σ of last stand -	(III) Inter-pass time between fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %	(V) Finishing temperature °C	
35	T	1346	969	73	75	56	65	2.0	7.0	8.0	94	822	Present Invention Example
36	U	1321	1024	67	73	72	77	3.0	4.0	7.0	61	938	Present Invention Example
37	V	1343	936	73	62	63	50	4.0	5.0	4.0	96	867	Present Invention Example
38	W	1161	850	47	52	46	48	5.0	5.0	6.0	61	901	Present Invention Example
39	X	1297	1039	73	53	69	71	2.0	3.0	6.0	83	899	Present Invention Example
40	Y	1324	917	71	71	53	43	3.0	3.0	5.0	82	831	Present Invention Example
41	Z	1300	904	56	68	71	64	6.0	7.0	3.0	70	882	Present Invention Example
42	<u>AA</u>	1270	976	42	77	56	42	4.0	3.0	8.0	83	874	Comparative Example

(continued)

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling									Note	
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand -	(II) σ of third stand from last stand -	(II) σ of second stand from last stand -	(II) σ of last stand -	(III) Inter-pass time between fourth stand from last stand and third stand from last stand s	(III) Inter-pass time between third stand from last stand and second stand from last stand s	(III) Inter-pass time between second stand from last stand and last stand s	(IV) Cumulative rolling reduction of last four stands %		(V) Finishing temperature °C
43	AB	1103	852	61	76	66	53	3.0	6.0	4.0	86	827	Comparative Example
44	AC	1288	914	62	69	59	78	6.0	5.0	9.0	72	843	Comparative Example
45	AD	1129	930	67	64	65	45	6.0	4.0	2.0	73	856	Comparative Example
46	<u>AE</u>	1332	1030	58	65	63	57	6.0	4.0	9.0	62	917	Comparative Example
47	A	1252	1038	71	58	66	56	6.0	3.0	5.0	77	906	Present Invention Example
48	B	1253	890	70	66	74	59	4.0	5.0	9.0	78	827	Comparative Example
49	D	1129	<u>820</u>	63	71	76	71	4.0	4.0	6.0	79	808	Comparative Example
50	E	1341	934	39	79	78	58	4.0	5.0	7.0	79	871	Comparative Example
51	C	1234	1033	55	<u>37</u>	50	68	4.0	7.0	9.0	77	831	Comparative Example
52	M	1313	975	51	<u>87</u>	43	47	5.0	2.0	3.0	as	869	Comparative Example

(continued)

Test No.	Kind of steel	Heating temperature of slab °C	Finish rolling										Note
			(1) Finish rolling start temperature °C	(II) σ of fourth stand from last stand -	(II) σ of third stand from last stand -	(II) σ of second stand from last stand -	(II) σ of last stand -	(III) Inter-pass time between fourth stand from last and third stand from last stand s	(III) Inter-pass time between third stand from last and second stand from last stand s	(III) Inter-pass time between second stand from last and last stand s	(IV) Cumulative rolling reduction of last four stands %	(V) Finishing temperature °C	
53	O	1266	940	46	78	35	63	3.0	4.0	6.0	92	930	Comparative Example
54	L	1300	1044	79	75	88	67	2.0	7.0	2.0	73	873	Comparative Example
55	Q	1278	1016	48	43	60	55	2.0	<u>12.0</u>	7.0	66	920	Comparative Example
56	F	1260	1001	44	51	52	61	6.0	6.0	<u>11.0</u>	62	855	Comparative Example
57	G	1306	1099	62	72	78	57	2.0	9.0	3.0	95	<u>1020</u>	Comparative Example
58	A	1257	893	48	48	61	57	2.0	4.0	6.0	71	893	Comparative Example
59	E	1274	1001	62	78	75	49	5.0	8.0	2.0	65	825	Comparative Example
60	C	1108	1022	45	63	47	62	3.0	3.0	9.0	77	937	Comparative Example
The underlined value indicates undesirable manufacturing conditions.													

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[Table 3A]

Test No.	Kind of steel	Air cooling time s	Average cooling rate from finishing temperature of air cooling to temperature range of 450°C to 550°C °C/s	Coiling temperature °C	Sheet thickness mm	Note
1	A	2.0	211	531	1.4	Present Invention Example
2	A	2.1	123	465	8.0	Present Invention Example
3	A	3.4	229	550	8.0	Present Invention Example
4	A	2.0	158	477	2.0	Present Invention Example
5	A	2.8	171	463	8.0	Comparative Example
6	B	3.4	158	465	5.0	Present Invention Example
7	B	3.2	208	485	4.0	Present Invention Example
8	B	3.0	160	469	3.0	Comparative Example
9	C	3.8	120	528	4.0	Present Invention Example
10	C	2.3	263	450	7.0	Present Invention Example
11	C	<u>1.2</u>	272	544	2.0	Comparative Example
12	D	3.9	265	545	2.0	Present Invention Example
13	D	3.3	124	461	4.0	Present Invention Example
14	D	2.3	146	486	1.2	Comparative Example
15	E	2.0	242	544	4.0	Present Invention Example
16	E	3.0	235	537	6.0	Present Invention Example

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(continued)

Test No.	Kind of steel	Air cooling time s	Average cooling rate from finishing temperature of air cooling to temperature range of 450°C to 550°C °C/s	Coiling temperature °C	Sheet thickness mm	Note
17	E	2.1	284	<u>330</u>	8.0	Comparative Example
18	F	2.9	218	513	8.0	Present Invention Example
19	F	2.7	106	485	1.9	Present Invention Example
20	F	3.9	235	485	1.7	Comparative Example
21	G	2.0	146	543	2.0	Present Invention Example
22	G	2.3	229	492	3.0	Present Invention Example
23	G	2.0	108	503	1.2	Comparative Example
24	<u>H</u>	<u>4.5</u>	<u>70</u>	<u>570</u>	5.0	Comparative Example
25	<u>I</u>	2.0	157	<u>420</u>	6.0	Comparative Example
26	<u>J</u>	2.0	133	480	6.0	Comparative Example
The underlined value indicates undesirable manufacturing conditions.						

[Table 3B]

Test No.	Kind of steel	Air cooling time s	Average cooling rate from finishing temperature of air cooling to temperature range of 450°C to 550°C °C/s	Coiling temperature °C	Sheet thickness mm	Note
27	K	2.5	141	483	1.4	Present Invention Example
28	L	2.3	216	478	8.0	Present Invention Example
29	M	3.2	241	521	8.0	Present Invention Example
30	O	2.1	182	525	2.0	Present Invention Example

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(continued)

5	Test No.	Kind of steel	Air cooling time s	Average cooling rate from finishing temperature of air cooling to temperature range of 450°C to 550°C °C/s	Coiling temperature °C	Sheet thickness mm	Note
10	31	P	3.4	245	523	8.0	Present Invention Example
15	32	Q	2.4	208	527	5.0	Present Invention Example
20	33	R	3.2	185	457	4.0	Present Invention Example
25	34	S	3.0	112	524	1.4	Present Invention Example
30	35	T	3.5	247	459	1.4	Present Invention Example
35	36	U	3.8	176	519	8.0	Present Invention Example
40	37	V	3.1	243	512	8.0	Present Invention Example
45	38	W	2.8	245	547	2.0	Present Invention Example
50	39	X	2.4	161	487	8.0	Present Invention Example
55	40	Y	2.7	149	497	5.0	Present Invention Example
	41	Z	2.8	216	453	4.0	Present Invention Example
	42	<u>AA</u>	2.7	215	492	3.0	Comparative Example
	43	<u>AB</u>	2.7	182	495	4.0	Comparative Example
	44	<u>AC</u>	3.0	146	533	7.0	Comparative Example
	45	<u>AD</u>	3.2	118	540	2.0	Comparative Example
	46	<u>AE</u>	3.7	212	464	2.0	Comparative Example

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(continued)

Test No.	Kind of steel	Air cooling time s	Average cooling rate from finishing temperature of air cooling to temperature range of 450°C to 550°C °C/s	Coiling temperature °C	Sheet thickness mm	Note
47	A	2.7	229	531	4.0	Present Invention Example
48	B	2.4	215	475	1.2	Comparative Example
49	D	2.2	238	453	4.0	Comparative Example
50	E	3.0	219	466	6.0	Comparative Example
51	C	3.2	228	468	8.0	Comparative Example
52	M	2.6	245	482	8.0	Comparative Example
53	O	2.6	217	462	1.9	Comparative Example
54	L	2.7	259	465	1.7	Comparative Example
55	Q	2.0	247	493	2.0	Comparative Example
56	F	3.0	218	503	3.0	Comparative Example
57	G	2.5	240	483	1.2	Comparative Example
58	A	<u>6.0</u>	120	487	5.0	Comparative Example
59	E	2.5	<u>90</u>	538	6.0	Comparative Example
60	C	2.4	151	<u>590</u>	6.0	Comparative Example
The underlined value indicates undesirable manufacturing conditions.						

[Table 4A]

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region		Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
		Retained austenite area%	Fresh martensite area%	Bainite area%		Pole density of {110}<112> orientation -					
1	A	14	6	80	6.6	2.9	981	2.3	47	Present Invention Example	
2	A	19	1	80	6.3	3.7	1014	3.0	46	Present Invention Example	
3	A	16	6	78	3.0	2.0	1095	0.7	44	Present Invention Example	
4	A	20	7	73	4.4	3.8	1027	-1.1	43	Present Invention Example	
5	A	18	7	75	4.5	5.2	1005	3.4	38	Comparative Example	
6	B	14	7	79	4.9	2.7	1006	-1.0	47	Present Invention Example	
7	B	10	6	84	6.9	2.5	1169	-0.5	41	Present Invention Example	
8	B	17	0	83	1.5	3.1	990	-3.6	37	Comparative Example	
9	C	19	2	79	5.1	3.6	1163	-2.0	47	Present Invention Example	
10	C	10	1	89	5.9	2.2	1083	-0.9	43	Present Invention Example	

(continued)

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region		Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
		Retained austenite area%	Fresh martensite area%	Bainite area%		Pole density of {110}<112> orientation -					
<u>11</u>	C	10	<u>31</u>	<u>59</u>	6.3	3.3	1440	<u>-4.1</u>	<u>29</u>	Comparative Example	
12	D	14	0	86	3.4	2.4	1027	2.2	43	Present Invention Example	
13	D	13	2	85	3.3	2.5	1185	-0.5	46	Present Invention Example	
<u>14</u>	D	19	4	77	<u>1.9</u>	<u>1.8</u>	1021	<u>5.1</u>	<u>37</u>	Comparative Example	
15	E	16	4	80	2.9	2.5	992	0.8	46	Present Invention Example	
16	E	17	1	82	6.1	4.0	1061	-0.9	43	Present Invention Example	
<u>17</u>	E	10	<u>33</u>	<u>57</u>	5.4	3.0	1350	<u>-4.5</u>	<u>29</u>	Comparative Example	
18	F	13	3	84	3.1	2.4	1113	0.7	41	Present Invention Example	
19	F	13	10	77	4.2	2.6	1062	1.5	43	Present Invention Example	
<u>20</u>	F	13	6	81	<u>1.7</u>	2.3	<u>978</u>	<u>-4.8</u>	<u>31</u>	Comparative Example	

(continued)

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region	Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
		Retained austenite area%	Fresh martensite area%	Bainite area%	Pole densities of {001} <110>, {111}<110>, and {112}<110> orientation groups -	Pole density of {110}<112> orientation -				
21	G	17	9	74	3.9	2.3	1100	0.5	40	Present Invention Example
22	G	20	6	74	4.0	2.7	1078	0.5	40	Present Invention Example
<u>23</u>	G	13	5	82	<u>8.5</u>	2.8	1129	<u>-4.5</u>	<u>35</u>	Comparative Example
<u>24</u>	H	<u>27</u>	0	73	2.9	<u>1.9</u>	<u>940</u>	<u>-3.3</u>	<u>32</u>	Comparative Example
<u>25</u>	I	14	<u>17</u>	<u>69</u>	5.4	3.0	1408	<u>-5.9</u>	<u>22</u>	Comparative Example
<u>26</u>	J	13	2	85	<u>1.9</u>	<u>5.8</u>	1109	<u>4.8</u>	<u>39</u>	Comparative Example
The underlined value indicates outside of the range of the present invention, or undesirable properties.										

[Table 4B]

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region		Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
		Retained austenite area%	Fresh martensite area%	Bainite area%		Pole density of {110}<112> orientation-					
27	K	14	6	80	6.6	2.5	981	2.3	47	Present Invention Example	
28	L	19	1	80	63	4.0	1014	3.0	46	Present Invention Example	
29	M	16	6	78	3.0	3.0	1095	0.7	44	Present Invention Example	
30	O	20	7	73	4.4	2.4	1027	-1.1	43	Present Invention Example	
31	P	18	7	75	4.5	2.6	1005	23	47	Present Invention Example	
32	Q	14	7	79	6.6	2.3	1006	3.0	46	Present Invention Example	
33	R	14	6	80	63	2.3	1169	0.7	44	Present Invention Example	
34	S	19	0	81	3.0	2.7	990	-1.1	43	Present Invention Example	
35	T	16	2	82	4.4	2.8	1163	2.3	47	Present Invention Example	

(continued)

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region		Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
		Retained austenite area%	Fresh martensite area%	Bainite area%		Pole densities of {110}<112> orientation-	Pole density of {110}<112> orientation-				
36	U	20	1	79	4.5	2.7	2.7	1083	3.0	46	Present Invention Example
37	V	18	6	76	4.9	2.5	2.5	1440	0.7	44	Present Invention Example
38	W	14	1	85	69	3.1	3.1	1027	-1.1	43	Present Invention Example
39	X	14	6	80	4.4	3.6	3.6	1185	2.3	47	Present Invention Example
40	Y	19	7	74	4.5	2.2	2.2	981	3.0	46	Present Invention Example
41	Z	14	7	79	4.9	3.3	3.3	1014	0.7	45	Present Invention Example
42	<u>AA</u>	19	7	74	<u>8.2</u>	2.4	2.4	1095	<u>-3.2</u>	<u>32</u>	Comparative Example
43	<u>AB</u>	16	6	78	6.6	<u>1.9</u>	<u>1.9</u>	981	<u>3.2</u>	<u>35</u>	Comparative Example
44	<u>AC</u>	20	0	80	63	<u>1.8</u>	<u>1.8</u>	1014	<u>3.3</u>	<u>36</u>	Comparative Example
45	<u>AD</u>	18	2	80	3.0	<u>1.6</u>	<u>1.6</u>	981	<u>-3.3</u>	<u>35</u>	Comparative Example

(continued)

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region		Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
		Retained austenite area%	Fresh martensite area%	Bainite area%		Pole density of {110}<112> orientation-					
46	AE	14	1	85	Pole densities of {001}<110>, {111}<110>, and {112}<110> orientation groups-	1.5	7.4	981	-3.8	29	Comparative Example
47	A	14	6	80	2.2	3.2	2.2	1014	2.3	42	Present Invention Example
48	B	8	6	86	2.3	1.9	2.3	1095	3.7	32	Comparative Example
49	D	12	1	87	0.5	5.3	0.5	979	-4.1	14	Comparative Example
50	E	10	6	84	2.3	1.9	2.3	1005	3.2	35	Comparative Example
51	C	10	6	84	1.8	3.0	1.8	1006	-4.1	33	Comparative Example
52	M	14	1	85	3.2	1.9	3.2	1169	3.5	32	Comparative Example
53	O	13	6	81	1.8	3.7	1.8	990	3.8	32	Comparative Example
54	L	19	7	74	2.8	5.2	2.8	1163	-3.4	33	Comparative Example
55	Q	16	7	77	1.5	4.3	1.5	1083	3.5	34	Comparative Example
56	F	17	7	76	6.6	5.2	6.6	1440	-3.3	37	Comparative Example
57	G	19	6	75	73	1.1	73	972	3.4	30	Comparative Example

(continued)

Test No.	Kind of steel	Microstructure			Surface layer region	Internal region	Tensile strength MPa	Difference between total elongation in C direction and total elongation in L direction %	hole expansion ratio %	Note
58	A	Retained austenite area%	Fresh martensite area%	Bainite area%	Pole densities of {001} <110>, {111}<110>, and {112}<110> orientation groups-	Pole density of {110}<112> orientation-	1185	-3.2	33	Comparative Example
59	E	33	2	65	7.3	4.6	1021	3.1	32	Comparative Example
60	C	29	1	70	79	4.7	970	-3.9	36	Comparative Example
The underlined value indicates outside of the range of the present invention, or undesirable properties.										

[0136] As can be understood from Tables 4A and 4B, it can be seen that the hot-rolled steel sheets according to the present invention examples having high strength, and excellent isotropy in ductility and hole expansibility were obtained.

[0137] On the other hand, in comparative examples in which the chemical composition and/or the microstructure were not within the ranges defined by the present invention, any one or more of the above properties were poor.

[Industrial Applicability]

[0138] According to the above aspect of the present invention, it is possible to provide a hot-rolled steel sheet having high strength, and excellent isotropy in ductility and hole expansibility.

Claims

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

C: 0.100% to 0.350%;

Si: 0.010% to 3.00%;

Mn: 1.00% to 4.00%;

sol. Al: 0.001% to 2.000%;

Si+sol.Al: 1.00% or more;

Ti: 0.010% to 0.380%;

P: 0.100% or less;

S: 0.0300% or less;

N: 0.1000% or less;

O: 0.0100% or less;

Nb: 0% to 0.100%;

V: 0% to 0.500%;

Cu: 0% to 2.00%;

Cr: 0% to 2.00%;

Mo: 0% to 1.00%;

Ni: 0% to 2.00%;

B: 0% to 0.0100%;

Ca: 0% to 0.0200%;

Mg: 0% to 0.0200%;

REM: 0% to 0.1000%;

Bi: 0% to 0.020%;

one, two or more of Zr, Co, Zn and W: 0 to 1.00% in total,

Sn: 0% to 0.050%; and

a remainder comprising Fe and impurities,

wherein a microstructure in a region from a depth of 1/8 of a sheet thickness from a surface to a depth of 3/8 of the sheet thickness from the surface comprises, by area%,

retained austenite: 10% to 20%,

fresh martensite: 10% or less, and

bainite: 70% to 90%,

in a texture of a region from the surface to the depth of 1/8 of the sheet thickness from the surface,

pole densities of {001}<110>, {111}<110>, and {112}<110> orientation groups are 2.0 to 8.0,

in a texture of a region from the depth of 1/8 of the sheet thickness from the surface to a depth of 1/2 of the sheet thickness from the surface,

a pole density of a {110}<112> orientation is 2.0 to 4.0, and

a tensile strength of the hot-rolled steel sheet is 980 MPa or more.

2. The hot-rolled steel sheet according to claim 1, wherein the chemical composition comprises by mass%, one or two or more selected from the group consisting of

Nb: 0.005 to 0.100%,

V: 0.005 to 0.500%,

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Cu: 0.01 to 2.00%,
Cr: 0.01 to 2.00%,
Mo: 0.01 to 1.00%,
Ni: 0.02 to 2.00%,
B: 0.0001 to 0.0100%,
Ca: 0.0005 to 0.0200%,
Mg: 0.0005 to 0.0200%,
REM: 0.0005 to 0.1000%, and
Bi: 0.0005 to 0.020%.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/038039

A. CLASSIFICATION OF SUBJECT MATTER C21D 9/46 (2006.01)i; C22C 38/00 (2006.01)i; C22C 38/58 (2006.01)i FI: C22C38/00 301W; C22C38/58; C21D9/46 T 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) C21D9/46; C22C38/00; C22C38/58 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2022 Registered utility model specifications of Japan 1996-2022 Published registered utility model applications of Japan 1994-2022 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)												
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>WO 2021/019947 A1 (JFE STEEL CORP.) 04 February 2021 (2021-02-04)</td> <td>1-2</td> </tr> <tr> <td>A</td> <td>WO 2016/167313 A1 (NIPPON STEEL & SUMITOMO METAL CORP.) 20 October 2016 (2016-10-20)</td> <td>1-2</td> </tr> <tr> <td>A</td> <td>WO 2016/158159 A1 (KK KOBE SEIKO SHO) 06 October 2016 (2016-10-06)</td> <td>1-2</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	A	WO 2021/019947 A1 (JFE STEEL CORP.) 04 February 2021 (2021-02-04)	1-2	A	WO 2016/167313 A1 (NIPPON STEEL & SUMITOMO METAL CORP.) 20 October 2016 (2016-10-20)	1-2	A	WO 2016/158159 A1 (KK KOBE SEIKO SHO) 06 October 2016 (2016-10-06)	1-2
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Date of the actual completion of the international search 22 December 2022	Date of mailing of the international search report 10 January 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/JP2022/038039

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