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(54) THICK STEEL SHEET AND MANUFACTURING METHOD THEREFOR

(57) Provided is a steel plate having excellent internal properties and high strength and capable of being produced at low cost with no need for special equipment. The steel plate comprises a predetermined chemical composition, a relationship Ceq/t ≥ 0.0015 is satisfied, and an area ratio of void defects at a thickness center position of the steel plate is 0.5 % or less.

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a steel plate and a production method therefor.

BACKGROUND

[0002] In recent years, structures are increasing in size in fields such as ships, line pipes, buildings, bridges, marine structures, wind power generators, construction machinery, and pressure vessels. Accordingly, steel plates used in these fields are also increasing in thickness.

[0003] As techniques related to such thick steel plates (hereafter also referred to as "steel plates") and production methods therefor, for example, JP S58-167045 A (PTL 1) discloses "A steel material hot forging method of performing extend forging on an axisymmetric steel material between an upper anvil and a lower anvil, comprising a step of forming a shape of a cross section perpendicular to an extend forging direction of the steel material into a rectangle or substantially rectangle whose ratio of a length of a long side and a length of a short side is at least 1.4, between start of the extend forging and end of the extend forging."

[0004] JP 6137080 B2 (PTL 2) discloses "A slab forging method comprising continuously subjecting a slab to reduction in a width direction and thereafter in a thickness direction using asymmetric anvils that are upper and lower anvils with different widths, wherein the reduction in the width direction is performed from one end in a longitudinal direction of the slab, at which time a ratio $\Delta L/B$ is limited to 0.20 or less where ΔL is an amount of deviation between end positions of the upper and lower anvils at the other end in the longitudinal direction of the slab and B is a shorter contact length out of respective contact lengths of the upper and lower anvils with the slab."

[0005] JP 6156321 B2 (PTL 3) discloses "A slab hot forging method comprising continuously subjecting a slab produced by continuous casting to reduction in a width direction and thereafter in a thickness direction using asymmetric upper and lower anvils, wherein the reduction of the slab in the width direction is performed in two stages of a first and second stages between which the slab is reversed and in each of which reduction is performed at least twice, the reduction of the slab in the width direction in each stage is performed using an anvil of 400 mm to 1200 mm in width as a short side anvil and an anvil of 800 mm to 1500 mm in width as a long side anvil while shifting a reduction phase at a reduction position by the short side anvil so that $\Delta L \leq 0.20B$ where ΔL is a deviation between a slab feed margin boundary during first reduction of the slab and a center of an anvil contact length (B) during next reduction, and each reduction ratio in the reduction of the slab in the width direction is 4 % or more and a total reduction ratio in the reduction of the slab in the thickness direction is 10 % or more".

[0006] JP H6-69569 B2 (PTL 4) discloses "A production method for an ultra-thick steel plate having excellent internal properties, comprising subjecting cast steel produced by continuous casting to broad side pass rolling in a rough rolling step and further performing rolling to a product thickness in a finish rolling step, wherein in the finish rolling step, rolling is performed in a plurality of passes at a rolling rate of 200 mm/sec to 350 mm/sec".

[0007] JP S59-74220 A (PTL 5) discloses "A production method for a high-toughness steel plate with excellent internal quality through continuous casting, comprising a sequential combination of: immediately after cutting a continuous cast strand of aluminum killed steel containing Al: 0.07 wt% or less into a hot slab with a certain length, hot charging the hot slab into a blooming soaking furnace, soaking the hot slab to a temperature of 1050 °C to 1150 °C, and performing slab rolling so that a value of a shape ratio R according to the following formula will be 0.5 or more; thereafter subjecting the slab to dehydrogenation treatment to reduce diffusible hydrogen contained in a thickness center part of the slab to 1.2 ppm or less; thereafter reheating the slab to 950 °C to 1050 °C and subjecting the slab to plate rolling to obtain a plate with a finished thickness planned to be a required thickness of 50 mm or more; and, after the plate rolling ends, performing accelerated cooling from Ar_3 or a temperature not lower than Ar_3 by 40 °C or more to 500 °C to 350 °C at a heat releasing rate of 15 °C or more per minute.

CITATION LIST

Patent Literature

[0008]

PTL 1: JP S58-167045 A

PTL 2: JP 6137080 B2

PTL 3: JP 6156321 B2

PTL 4: JP H6-69569 B2

PTL 5: JP S59-74220 A

SUMMARY

(Technical Problem)

[0009] Steel plates are thick, and therefore have a high risk of fractures such as ductile fractures, brittle fractures, and fatigue fractures. Hence, a steel plate having excellent internal properties with a reduced risk of such fractures is needed. With steel plates produced using the techniques in PTL 1 to PTL 5, however, the risk of such fractures cannot always be reduced sufficiently and excellent internal properties cannot be obtained in some cases.

[0010] The techniques in PTL 1 to PTL 3 involve hot forging a slab. The production efficiency of hot forging is much lower than the production efficiency of hot rolling. Thus, the production capacity is low and the production costs are high.

[0011] The techniques in PTL 4 and PTL 5 involve hot rolling a slab instead of hot forging, but require reduction by rolling (hereinafter referred to as rolling reduction) with a high rolling shape ratio. In order to apply rolling reduction with a high rolling shape ratio in a stage in which the slab is thick, the rolling reduction amount per pass needs to be increased. This requires introducing an expensive rolling line with a high upper limit of load capacity and a high upper limit of torque.

[0012] Moreover, weight reduction of large structures is desired in recent years. There is thus a need to further improve the strength, in particular yield stress, of steel plates.

[0013] It could therefore be helpful to provide a steel plate having excellent internal properties and high strength and capable of being produced at low cost (i.e. with high productivity) with no need for special equipment. It could also be helpful to provide a production method for the steel plate.

(Solution to Problem)

[0014] Upon careful examination, we discovered the following:

- A slab, which is a rolling or forging material of a steel plate, is typically produced by continuous casting, ingot casting, or the like. Therefore, the final solidification position is usually near the thickness center position of the slab. When molten steel solidifies, volumetric shrinkage occurs. This inevitably causes void defects near the thickness center position of the slab. Such void defects serve as initiation points for fractures such as ductile fractures, brittle fractures, and fatigue fractures. When the amount of void defects is greater, fractures occur more frequently.
- An effective way of reducing the amount of void defects that form near the thickness center position of the slab is to increase the amount of strain introduced near the position during hot rolling. However, the distribution of strain in the thickness direction introduced into the slab by hot rolling is greatest near the surface of the slab that is in contact with the rolling rolls, and decreases toward the thickness center. Thus, the amount of strain is smallest and the void defect annihilation ability is lowest at the thickness center position of the slab.

[0015] We conducted various studies in order to increase the amount of strain near the thickness center position of the slab during hot rolling without using special equipment.

[0016] We consequently discovered the following:

- By performing rolling reduction with at least a certain temperature difference between the surface and the thickness center position of the slab, it is possible to increase the deformation resistance near the surface of the slab relative to the thickness center position of the slab and reduce the amount of strain applied near the surface of the slab. The amount of strain applied near the thickness center position of the slab can be increased by this reduction in the amount of strain applied near the surface of the slab.
- By performing rolling reduction in a state in which the temperature at the thickness center position of the slab is at least a certain level, specifically 700 °C or more, it is possible to close void defects by rolling strain and annihilate them through metal bonding more advantageously.

[0017] We conducted further studies based on these discoveries, and discovered that the amount of void defects that form near the thickness center position of the slab can be significantly reduced particularly by increasing the rolling reduction ratio in the rolling passes that satisfy the following (a) and (b):

(a) the temperature at the thickness center position of the slab: 700 °C or more, and
(b) the temperature difference between the surface and the thickness center position of the slab: 100 °C or more.

[0018] We conducted further studies, and discovered the following:

- By limiting the area ratio of void defects at the thickness center position of the steel plate to 0.5 % or less, it is possible to obtain excellent internal properties with a sufficiently reduced risk of fractures.
- An effective way of limiting the area ratio of void defects at the thickness center position of the steel plate to 0.5 % or less is to set the total rolling reduction ratio in the rolling passes that satisfy the foregoing (a) and (b) in the hot rolling step to more than 30 %.

[0019] Moreover, we conducted studies in order to achieve higher strength, specifically, a yield stress of 325 MPa or more, while ensuring excellent internal properties, and discovered the following:
It is effective to appropriately control Ceq defined by the following formula (1) depending on the thickness of the steel plate, specifically, to satisfy the relationship Ceq/t ≥ 0.0015:

$$\mathrm{Ceq} = [\mathrm{C}] + [\mathrm{Mn}]/6 + ([\mathrm{Cr}] + [\mathrm{Mo}] + [\mathrm{V}])/5 + ([\mathrm{Cu}] + [\mathrm{Ni}])/15 \ldots (1).$$

[0020] We also discovered that it is effective to, during cooling after hot rolling, set the cooling rate when passing the transformation temperature range from austenite microstructure, specifically, the average cooling rate in the temperature range from 700 °C to 600 °C at the position of 1/4 of the thickness of the hot-rolled steel plate, to $6000t^{-1.8}$ or more depending on the thickness t (mm) of the hot-rolled steel plate.
[0021] The present disclosure is based on these discoveries and further studies.
[0022] We thus provide the following.

[1] A steel plate comprising a chemical composition containing (consisting of), in mass%, C: 0.04 % to 0.18 %, Si: 0.03 % to 0.70 %, Mn: 0.30 % to 2.50 %, P: 0.030 % or less, S: 0.0200 % or less, Al: 0.001 % to 0.100 %, O: 0.0100 % or less, and N: 0.0100 % or less with a balance consisting of Fe and inevitable impurities, wherein Ceq defined by the following formula (1) and a thickness t in mm of the steel plate satisfy a relationship Ceq/t ≥ 0.0015:

$$\mathrm{Ceq} = [\mathrm{C}] + [\mathrm{Mn}]/6 + ([\mathrm{Cr}] + [\mathrm{Mo}] + [\mathrm{V}])/5 + ([\mathrm{Cu}] + [\mathrm{Ni}])/15 \ldots (1)$$

where each bracketed element symbol in the formula (1) represents a content in mass% of a corresponding element in the chemical composition, and is set to 0 in the case where the element is not contained, an area ratio of void defects at a thickness center position of the steel plate is 0.5 % or less, and a yield stress is 325 MPa or more.
[2] The steel plate according to [1], wherein the chemical composition further contains, in mass%, one or more selected from the group consisting of Cu: 2.00 % or less, Ni: 2.50 % or less, Cr: 1.50 % or less, Mo: 1.00 % or less, Nb: 0.100 % or less, Ti: 0.100 % or less, V: 0.30 % or less, B: 0.0100 % or less, W: 0.50 % or less, Ca: 0.0200 % or less, Mg: 0.0200 % or less, and REM: 0.0500 % or less.
[3] A production method for the steel plate according to [1] or [2], the production method comprising: preparing a slab having the chemical composition according to [1] or [2]; hot rolling the slab to obtain a hot-rolled steel plate; and cooling the hot-rolled steel plate, wherein a total rolling reduction ratio in rolling passes that satisfy the following (a) and (b) in the hot rolling is more than 30 %: (a) a temperature at a thickness center position of the slab: 700 °C or more, and (b) a temperature difference between a surface and the thickness center position of the slab: 100 °C or more, and in the cooling, an average cooling rate in °C/s in a temperature range from 700 °C to 600 °C at a position of 1/4 of a thickness of the hot-rolled steel plate is $6000t^{-1.8}$ or more, where t is the thickness in mm of the hot-rolled steel plate.
[4] The production method according to [3], further comprising subjecting the hot-rolled steel plate to a tempering treatment at a tempering temperature of 650 °C or less, after the cooling.

(Advantageous Effect)

[0023] It is thus possible to obtain a steel plate having excellent internal properties and high strength and capable of being produced at low cost with no need for special equipment.
[0024] A steel plate according to the present disclosure is not limited to any particular use, and can be used in a wide range of fields in which steel plates are typically used, such as ships, line pipes, buildings, bridges, marine structures, wind power generators, construction machinery, and pressure vessels.

DETAILED DESCRIPTION

[0025] A steel plate according to the present disclosure will be described below by way of embodiments.

[0026] First, the chemical composition of a steel plate according to one embodiment of the present disclosure will be described. While the unit of the content of each element in the chemical composition is "mass%", the content is expressed simply in "%" unless otherwise specified.

C: 0.04 % to 0.18 %

[0027] C is an element that can improve the strength of the steel at the lowest cost. If the C content is less than 0.04 %, the desired strength cannot be obtained. If the C content is more than 0.18 %, weldability decreases, and also toughness decreases. The C content is therefore 0.04 % to 0.18 %. The C content is preferably 0.05 % or more. The C content is preferably 0.17 % or less.

Si: 0.03 % to 0.70 %

[0028] Si is an element effective for deoxidation. If the Si content is less than 0.03 %, the effect is insufficient. If the Si content is more than 0.70 %, weldability decreases. The Si content is therefore 0.03 % to 0.70 %. The Si content is preferably 0.04 % or more. The Si content is preferably 0.60 % or less.

Mn: 0.30 % to 2.50 %

[0029] Mn is an element that improves the quench hardenability of the steel and improves the strength of the steel at low cost. In order to achieve such an effect, the Mn content is 0.30 % or more. If the Mn content is more than 2.50 %, weldability decreases. The Mn content is therefore 0.30 % to 2.50 %. The Mn content is preferably 0.50 % or more. The Mn content is preferably 2.20 % or less.

P: 0.030 % or less

[0030] P is an element that has a strong effect of embrittling grain boundaries. If the P content is high, the toughness of the steel decreases. The P content is therefore 0.030 % or less. The P content is preferably 0.025 % or less. Since a lower P content is more desirable, no lower limit is placed on the P content, and the P content may be 0 %. However, P is an element that is inevitably contained in steel as impurities, and an excessively low P content leads to longer refining time and higher cost. Accordingly, the P content is preferably 0.001 % or more.

S: 0.0200 % or less

[0031] S decreases the toughness of the steel. The S content is therefore 0.0200 % or less. The S content is preferably 0.0100 % or less. Since a lower S content is more desirable, no lower limit is placed on the S content, and the S content may be 0 %. However, S is an element that is inevitably contained in steel as impurities, and an excessively low S content leads to longer refining time and higher cost. Accordingly, the S content is preferably 0.0001 % or more.

Al: 0.001 % to 0.100 %

[0032] Al is an element effective for deoxidation. Al also has the effect of reducing the austenite grain size by forming nitrides. In order to achieve these effects, the Al content is 0.001 % or more. If the Al content is more than 0.100 %, the cleanliness of the steel decreases. This results in decreases in ductility and toughness. The Al content is therefore 0.001 % to 0.100 %. The Al content is preferably 0.005 % or more. The Al content is preferably 0.080 % or less.

O: 0.0100 % or less

[0033] O is an element that decreases ductility and toughness. The O content is therefore 0.0100 % or less. Since a lower O content is more desirable, no lower limit is placed on the O content, and the O content may be 0 %. However, O is an element that is inevitably contained in steel as impurities, and an excessively low O content leads to longer refining time and higher cost. Accordingly, the O content is preferably 0.0005 % or more.

N: 0.0100 % or less

[0034] N is an element that decreases ductility and toughness. The N content is therefore 0.0100 % or less. Since a lower N content is more desirable, no lower limit is placed on the N content, and the N content may be 0 %. However, N is an element that is inevitably contained in steel as impurities, and the N content may be more than 0 % industrially. An excessively low N content leads to longer refining time and higher cost. Accordingly, the N content is preferably 0.0005 % or more.

[0035] While the basic chemical composition of the steel plate according to one embodiment of the present disclosure has been described above, the chemical composition may optionally further contain one or more of the following elements as optional components from the viewpoint of further improving strength and weldability (such as weld toughness and welding activity):

Cu: 2.00 % or less,
Ni: 2.50 % or less,
Cr: 1.50 % or less,
Mo: 1.00 % or less,
Nb: 0.100 % or less,
Ti: 0.100 % or less,
V: 0.30 % or less,
B: 0.0100 % or less,
W: 0.50 % or less,
Ca: 0.0200 % or less,
Mg: 0.0200 % or less, and
REM: 0.0500 % or less.

Cu: 2.00 % or less

[0036] Cu is an element that improves the strength of the steel without greatly degrading toughness. If the Cu content is more than 2.00 %, hot cracking is caused by a Cu-enriched layer formed directly below scale. Accordingly, in the case where Cu is contained, the Cu content is preferably 2.00 % or less. The Cu content is more preferably 0.01 % or more. The Cu content is more preferably 1.50 % or less.

Ni: 2.50 % or less

[0037] Ni is an element that enhances the quench hardenability of the steel. Ni also has the effect of improving toughness. If the Ni content is more than 2.50 %, the production costs increase. Accordingly, in the case where Ni is contained, the Ni content is preferably 2.50 % or less. The Ni content is more preferably 0.01 % or more. The Ni content is more preferably 2.00 % or less.

Cr: 1.50 % or less

[0038] Cr is an element that improves the strength of the steel by improving the quench hardenability of the steel. If the Cr content is more than 1.50 %, weldability decreases. Accordingly, in the case where Cr is contained, the Cr content is preferably 1.50 % or less. The Cr content is more preferably 0.01 % or more. The Cr content is more preferably 1.20 % or less.

Mo: 1.00 % or less

[0039] Mo is an element that improves the strength of the steel by improving the quench hardenability of the steel. If the Mo content is more than 1.00 %, weldability decreases. Accordingly, in the case where Mo is contained, the Mo content is preferably 1.00 % or less. The Mo content is more preferably 0.01 % or more. The Mo content is more preferably 0.80 % or less.

Nb: 0.100 % or less

[0040] Nb is an element that suppresses recrystallization when strain is applied to austenite microstructure, by solute Nb or finely precipitated NbC. Nb also has the effect of raising the non-recrystallization temperature range. If the Nb content is more than 0.100 %, weldability decreases. Accordingly, in the case where Nb is contained, the Nb content is preferably 0.100 % or less. The Nb content is more preferably 0.001 % or more, and further preferably 0.005 % or more. The Nb content is more preferably 0.075 % or less, and further preferably 0.050 % or less.

Ti: 0.100 % or less

[0041] Ti is an element that has the effect of, by precipitating as TiN, pinning crystal grain boundaries and inhibiting grain growth. If the Ti content is more than 0.100 %, the cleanliness of the steel decreases. This results in decreases in ductility and toughness. Accordingly, in the case where Ti is contained, the Ti content is preferably 0.100 % or less. The Ti content is more preferably 0.001 % or more. The Ti content is more preferably 0.080 % or less.

V: 0.30 % or less

[0042] V is an element that improves the strength of the steel by improving the quench hardenability of the steel and forming carbonitrides. If the V content is more than 0.30 %, weldability decreases. Accordingly, in the case where V is contained, the V content is preferably 0.30 % or less. The V content is more preferably 0.01 % or more. The V content is more preferably 0.25 % or less.

B: 0.0100 % or less

[0043] B is an element that improves the strength of the steel by improving the quench hardenability of the steel. If the B content is more than 0.0100 %, weldability decreases. Accordingly, in the case where B is contained, the B content is preferably 0.0100 % or less. The B content is more preferably 0.0001 % or more. The B content is more preferably 0.0070 % or less.

W: 0.50 % or less

[0044] W is an element that improves the strength of the steel by improving the quench hardenability of the steel. If the W content is more than 0.50 %, weldability decreases. Accordingly, in the case where W is contained, the W content is preferably 0.50 % or less. The W content is more preferably 0.01 % or more. The W content is more preferably 0.40 % or less.

Ca: 0.0200 % or less

[0045] Ca is an element that improves weldability by forming oxysulfides having high stability at high temperature. If the Ca content is more than 0.0200 %, the cleanliness of the steel decreases and the toughness of the steel decreases. Accordingly, in the case where Ca is contained, the Ca content is preferably 0.0200 % or less. The Ca content is more preferably 0.0001 % or more. The Ca content is more preferably 0.0180 % or less.

Mg: 0.0200 % or less

[0046] Mg is an element that improves weldability by forming oxysulfides having high stability at high temperature. If the Mg content is more than 0.0200 %, the Mg addition effect is saturated and the effect appropriate to the content cannot be expected, which is economically disadvantageous. Accordingly, in the case where Mg is contained, the Mg content is preferably 0.0200 % or less. The Mg content is more preferably 0.0001 % or more. The Mg content is more preferably 0.0180 % or less.

REM: 0.0500 % or less

[0047] REM (rare earth metal) is an element that improves weldability by forming oxysulfides having high stability at high temperature. If the REM content is more than 0.0500 %, the REM addition effect is saturated and the effect appropriate to the content cannot be expected, which is economically disadvantageous. Accordingly, in the case where REM is contained, the REM content is preferably 0.0500 % or less. The REM content is more preferably 0.0001 % or more. The REM content is more preferably 0.0450 % or less.

[0048] The balance other than the foregoing elements in the chemical composition of the steel plate according to one embodiment of the present disclosure consists of Fe and inevitable impurities. If the content of any of the foregoing elements as optional components is less than the preferable lower limit, the element is treated as inevitable impurities.

[0049] It is important that, in the steel plate according to one embodiment of the present disclosure, Ceq defined by the following formula (1) and the thickness t (mm) of the steel plate satisfy the relationship $Ceq/t \geq 0.0015$:

$$Ceq = [C] + [Mn]/6 + ([Cr] + [Mo] + [V])/5 + ([Cu] + [Ni])/15 \ldots \quad (1)$$

where each bracketed element symbol in the formula (1) represents the content (mass%) of the corresponding element in the chemical composition, and is set to 0 in the case where the element is not contained.

$Ceq/t \geq 0.0015$

[0050] Ceq is a parameter that correlates with the strength of the steel microstructure. As a result of the ratio of Ceq to the thickness t (mm) of the steel plate being appropriately controlled, specifically, as a result of Ceq/t being 0.0015 or more, the desired yield stress can be obtained. Ceq/t is therefore 0.0015 or more. Ceq/t is preferably 0.0018 or more. Although no upper limit is placed on Ceq/t, for example, Ceq/t is preferably 0.0200 or less.

[0051] It is very important that, in the steel plate according to one embodiment of the present disclosure, the area ratio of void defects at the thickness center position is 0.5 % or less.

Area ratio of void defects at thickness center position: 0.5 % or less

[0052] Void defects inside a steel plate serve as initiation points for fractures such as ductile fractures, brittle fractures, and fatigue fractures. In particular, if a large amount of void defects remain at the thickness center position of the steel plate, specifically, if the area ratio of void defects at the thickness center position is more than 0.5 %, the frequency of such fractures is high, and a steel plate having excellent internal properties cannot be obtained. The area ratio of void defects at the thickness center position is therefore 0.5 % or less. The area ratio of void defects at the thickness center position is preferably 0.3 % or less. No lower limit is placed on the area ratio of void defects at the thickness center position, and the area ratio of void defects at the thickness center position may be 0 %.

[0053] The area ratio of void defects at the thickness center position is measured in the manner described in the EXAMPLES section below. Herein, the expression "excellent internal properties" means that the area reduction ratio in the thickness direction of the steel plate measured in a tensile test in accordance with ASTM A370 (2010) is 35 % or more. Detailed test conditions are as described in [Tensile test in thickness direction] in the EXAMPLES section below.

[0054] The expression "high strength" means that the yield stress measured in a tensile test in accordance with JIS Z2241 (2011) is 325 MPa or more. Detailed test conditions are as described in [Tensile test in width direction] in the EXAMPLES section below.

[0055] The steel microstructure of the steel plate according to one embodiment of the present disclosure is not limited, but is preferably microstructure mainly composed of fine microstructures having an average grain size of 15 μm or less from the viewpoint of more advantageously obtaining the desired strength.

[0056] Herein, the "microstructure mainly composed of fine microstructures having an average grain size of 15 μm or less" means that the total area ratio of ferrite and bainite to the entire steel microstructure is 60 % or more and the average grain size (equivalent circular diameter of large-angle grain boundaries) of ferrite and bainite is 15 μm or less. Examples of residual microstructures other than ferrite and bainite include pearlite and martensite. The total area ratio of the residual microstructures to the entire steel microstructure is preferably 40 % or less.

[0057] The area ratio and average grain size of each microstructure may be measured according to conventional methods. For example, optical microscope photographs or scanning electron microscopes may be used for the measurement. The area ratio and average grain size of each microstructure are measured at the thickness center position.

[0058] The thickness of the steel plate according to one embodiment of the present disclosure is preferably 30 mm to 240 mm. The thickness of the steel plate according to one embodiment of the present disclosure is more preferably 50 mm or more, and further preferably 101 mm or more. The thickness of the steel plate according to one embodiment of the present disclosure is more preferably 230 mm or less.

[0059] Next, a production method for the steel plate according to one embodiment of the present disclosure will be described.

[0060] The production method for the steel plate according to one embodiment of the present disclosure comprises: preparing a slab (steel material) having the foregoing chemical composition (preparation step); hot rolling the slab to obtain a hot-rolled steel plate (hot rolling step); and cooling the hot-rolled steel plate (cooling step), wherein the total rolling reduction ratio in rolling passes that satisfy the following (a) and (b) in the hot rolling is more than 30 %:

(a) the temperature at the thickness center position of the slab: 700 °C or more, and
(b) the temperature difference between the surface and the thickness center position of the slab: 100 °C or more, and

in the cooling, the average cooling rate (°C/s) in the temperature range from 700 °C to 600 °C at the position of 1/4 of the thickness of the hot-rolled steel plate is $6000t^{-1.8}$ or more, where t is the thickness (mm) of the hot-rolled steel plate.

[0061] Here, since the thickness of the steel plate (as the finished product) and the thickness of the hot-rolled steel plate are often the same, both thicknesses are denoted by t.

[0062] Thus, the steel plate according to one embodiment of the present disclosure can be produced favorably. Each step will be described below.

[0063] The surface temperature of each of the slab and the steel plate can be measured using a radiation thermometer, for example. The temperature at the thickness center position of the slab can be measured, for example, by attaching a thermocouple at the thickness center position of the slab, or by calculating the temperature distribution in the cross section of the slab by thermal analysis and correcting the result using the surface temperature of the slab. The temperature at the position of 1/4 of the thickness of the hot-rolled steel plate can be measured in the same way. Hereafter, the temperature of each of the slab and the steel plate denotes the surface temperature unless otherwise specified. Here, the material to be rolled during the hot rolling step is hereafter referred to as "slab" and not "steel plate" (hot-rolled steel plate) and the steel plate obtained through the hot rolling step is referred to as "hot-rolled steel plate", for the sake of convenience.

[Preparation step]

[0064] In the preparation step, a slab having the foregoing chemical composition is prepared. The preparation method is not limited. For example, molten steel is obtained by a known steelmaking method such as a converter, an electric furnace, or a vacuum melting furnace. Secondary refining such as ladle refining may be optionally performed. The obtained molten steel is then made into a slab by continuous casting, ingot casting, or the like, and thus a slab having the foregoing chemical composition is prepared. Conditions may be according to conventional methods.

[Hot rolling step]

[0065] Following this, the slab prepared in the preparation step is optionally heated, and subjected to hot rolling to obtain a hot-rolled steel plate. It is very important to satisfy the following conditions in the hot rolling.

[0066] Total rolling reduction ratio in rolling passes that satisfy (a) and (b) (hereafter also referred to as "rolling passes under the predetermined conditions"): more than 30 %

(a) the temperature at the thickness center position of the slab: 700 °C or more, and
(b) the temperature difference between the surface and the thickness center position of the slab: 100 °C or more

[0067] An effective way of closing void defects present near the thickness center position of the slab and annihilating them through metal bonding is to apply strain in a state in which the temperature at the thickness center position of the slab is 700 °C or more. In order to increase the amount of strain applied near the thickness center position of the slab, it is necessary to perform rolling in a state in which the temperature difference between the surface and the thickness center position of the slab is 100 °C or more. From the viewpoint of ensuring the amount of strain necessary for closing and annihilating void defects present near the thickness center position of the slab, the total rolling reduction ratio in the rolling passes under the predetermined conditions is more than 30 %. The total rolling reduction ratio in the rolling passes under the predetermined conditions is preferably 40 % or more. Although no upper limit is placed on the total rolling reduction ratio in the rolling passes under the predetermined conditions, the total rolling reduction ratio in the rolling passes under the predetermined conditions is preferably 65 % or less.

[0068] The total rolling reduction ratio in the rolling passes under the predetermined conditions is calculated using the following formula (1):

$$r_t = 100 \times \{(t_{i1} - t_{f1})/t_{i1} + (t_{i2} - t_{f2})/t_{i2} + (t_{i3} - t_{f3})/t_{i3} + \ldots + (t_{iN} - t_{fN})/t_{iN}\} \quad \ldots (1),$$

where r_t is the total rolling reduction ratio (%) in the rolling passes under the predetermined conditions, t_{iN} is the thickness (mm) of the slab at the start of rolling in the Nth rolling pass among the rolling passes under the predetermined conditions, t_{fN} is the thickness (mm) of the slab at the end of rolling in the Nth rolling pass among the rolling passes under the predetermined conditions, and N is the number of rolling passes under the predetermined conditions.

[0069] Whether the temperature conditions (a) and (b) are satisfied is determined based on the surface temperature of the slab and the temperature at the thickness center position of the slab at the start of rolling in each rolling pass.

[0070] The method of adjusting the temperature difference between the surface and the thickness center position of the slab is not limited. For example, the temperature difference between the surface and the thickness center position of the slab can be adjusted to the foregoing range by forced-cooling the surface of the slab through air cooling, water cooling, or the like.

[0071] Conditions other than the above are not limited and may be according to conventional methods.

[0072] For example, the slab heating temperature is preferably 950 °C to 1300 °C. The total number of rolling passes in the hot rolling is preferably 5 passes to 60 passes. N (the number of rolling passes under the predetermined conditions) is preferably 5 passes to 50 passes. The rolling reduction ratio in the hot rolling (= [the thickness (mm) of the slab at the start of the hot rolling (i.e. the start of the first rolling pass)]/[the thickness (mm) of the hot-rolled steel plate obtained after the end of the hot rolling (i.e. the end of the final rolling pass)]) is preferably 1.6 to 16. The rolling finish temperature (i.e. the delivery temperature in the final pass) is preferably 700 °C to 1000 °C.

[Cooling step]

[0073] Next, the hot-rolled steel plate is cooled. It is very important to satisfy the following conditions in the cooling.

[0074] Average cooling rate (°C/s) in temperature range from 700 °C to 600 °C at position of 1/4 of thickness of hot-rolled steel plate: $6000t^{-1.8}$ or more

[0075] An effective way of achieving higher strength, specifically, a yield stress of 325 MPa or more, while ensuring excellent internal properties is to increase the cooling rate when passing the transformation temperature range from austenite microstructure, in particular when passing the temperature range from 700 °C to 600 °C at the position of 1/4 of the thickness of the hot-rolled steel plate, depending on the thickness t (mm) of the hot-rolled steel plate. The average cooling rate in the temperature range from 700 °C to 600 °C (hereafter also referred to as "average cooling rate from 700 °C to 600 °C") at the position of 1/4 of the thickness of the hot-rolled steel plate is therefore $6000t^{-1.8}$ or more. The average cooling rate from 700 °C to 600 °C is preferably $7000t^{-1.8}$ or more. The average cooling rate from 700 °C to 600 °C is preferably $30000t^{-1.8}$ or less.

[0076] Conditions other than the above are not limited and may be according to conventional methods. Examples of the cooling method include water cooling and gas cooling. The cooling rates in the temperature ranges other than the above are not limited, and any cooling method may be used to cool the hot-rolled steel plate to room temperature.

[Tempering step]

[0077] After the cooling step, the hot-rolled steel plate may be optionally subjected to a tempering treatment in order to adjust the strength, ductility, toughness, etc. If the tempering temperature is more than 650 °C, softening proceeds excessively and the desired yield stress cannot be obtained. Therefore, in the case of performing the tempering treatment, the tempering temperature is 650 °C or less. Conditions other than the above are not limited and may be according to conventional methods. The tempering temperature herein is the temperature at the position of 1/4 of the thickness of the hot-rolled steel plate during soaking.

EXAMPLES

[0078] Molten steels having the chemical compositions shown in Table 1 were obtained by steelmaking, and slabs of 260 mm to 600 mm in thickness were prepared by continuous casting, ingot casting, or the like. Each blank space in the element columns in Table 1 indicates that the element is not intentionally added, including not only the case where the element is not contained (0 %) but also the case where the element is inevitably contained.

[0079] Each prepared slab was then subjected to hot rolling and cooling and also a tempering treatment was performed for some of them under the conditions shown in Table 2, to obtain a steel plate having the thickness t (mm) shown in Table 2. Since the thickness of the steel plate and the thickness of the hot-rolled steel plate are the same, they are indicated as "thickness t" in Table 2. In Table 2, "-" in the tempering temperature column means that no tempering treatment was performed. The rolling reduction ratio in the hot rolling was in the range of 2.5 to 3.5, and N (the number of rolling passes under the predetermined conditions) was 5 passes to 37 passes. The surface temperature of the slab was measured using a radiation thermometer, and the temperature of the thickness center of the slab and the temperature at the position of 1/4 of the thickness of the hot-rolled steel plate were measured using a thermocouple. The temperature difference between the surface and the thickness center position of the slab was adjusted by forced-cooling the surface of the slab through air cooling, water cooling, or the like. Conditions other than the above were according to conventional methods.

[0080] For each obtained steel plate, the area ratio of void defects at the thickness center position was measured in the following manner. The measurement results are shown in Table 2. In each Example, microstructure mainly composed of ferrite and bainite, in particular, microstructure mainly composed of fine microstructures having an average grain size of 15 μm or less, was obtained.

[Measurement of area ratio of void defects at thickness center position]

[0081] From each obtained steel plate, a sample for the entire width of the steel plate was collected at the center position in the longitudinal direction (i.e. the rolling direction) of the steel plate so that the cross section in the width direction (i.e. the direction orthogonal to the rolling direction) of the steel plate at the thickness center position of the steel plate would be the evaluation plane. The obtained sample was then mirror polished through alumina buffing for finish. Setting the evaluation region in the sample to the thickness center position ± 3 mm in the thickness direction and the entire plate width in the width direction, the area ratio of void defects in the evaluation region was measured through image analysis. The measured value was taken to be the area ratio of void defects at the thickness center position.

[0082] Moreover, for each obtained steel plate, a tensile test in the thickness direction and a tensile test in the width direction were conducted to evaluate the internal properties and yield stress in the following manner. The evaluation results are shown in Table 2.

[Tensile test in thickness direction]

[0083] From each obtained steel plate, a tensile test piece was collected at the center position in the longitudinal direction (i.e. the rolling direction) of the steel plate so that the longitudinal direction of the tensile test piece would be parallel to the thickness direction of the steel plate. Here, the tensile test piece was collected so that the longitudinal center position of the tensile test piece would be the thickness center position (i.e. the position of 1/2 of the thickness) of the steel plate. Such tensile test pieces were collected over the entire width of the steel plate with a collection pitch of 100 mm in the width direction of the steel plate. The shape of the tensile test piece was Type 3 shape in ASTM A770 (2007). Next, a tensile test in accordance with ASTM A370 (2010) was conducted using each collected tensile test piece, and the area reduction ratio was measured. The minimum value from among the reductions of area measured for the respective tensile test pieces collected over the entire width of the steel plate was then taken to be the area reduction ratio of the steel plate. In the case where this value was 35 % or more, the steel plate was evaluated as having excellent internal properties.

[Tensile test in width direction]

[0084] From each obtained steel plate, a tensile test piece was collected at the center position in the longitudinal direction (i.e. the rolling direction) of the steel plate so that the longitudinal direction of the tensile test piece would be parallel to the width direction (i.e. the direction orthogonal to the rolling direction) of the steel plate. Here, the tensile test piece was collected so that the thickness center position of the tensile test piece would be the position of 1/4 of the thickness of the steel plate. Such tensile test pieces were collected over the entire width of the steel plate with a collection pitch of 500 mm in the width direction of the steel plate. The shape of the tensile test piece was JIS No. 4 shape. Next, a tensile test in accordance with JIS Z2241 (2011) was conducted using each collected tensile test piece, and the yield stress was measured. The minimum value from among the yield stresses measured for the respective tensile test pieces collected over the entire width of the steel plate was then taken to be the yield stress of the steel plate. In the case where this value was 325 MPa or more, the steel plate was evaluated as having high strength.

[Table 1]

Table 1

Steel sample ID	Chemical composition (mass%) *1,2,3																				Ceq	Remarks
	C	Si	Mn	P	S	Al	O	N	Cu	Ni	Cr	Mo	Nb	Ti	V	B	W	Ca	Mg	REM		
A	0.05	0.29	1.31	0.004	0.0031	0.021	0.0015	0.0042													0.27	Conforming steel
B	0.12	0.09	0.79	0.021	0.0085	0.039	0.0030	0.0028													0.25	Conforming steel
C	0.17	0.65	0.38	0.007	0.0005	0.003	0.0012	0.0020													0.23	Conforming steel
D	0.08	0.31	2.45	0.011	0.0015	0.016	0.0008	0.0015													0.49	Conforming steel
E	0.10	0.14	1.64	0.009	0.0152	0.083	0.0024	0.0034													0.37	Conforming steel
F	0.14	0.42	1.45	0.007	0.0013	0.031	0.0022	0.0075	0.88												0.44	Conforming steel
G	0.07	0.50	0.65	0.005	0.0008	0.019	0.0031	0.0054		1.35											0.27	Conforming steel
H	0.15	0.04	1.53	0.002	0.0004	0.008	0.0085	0.0024			0.79										0.56	Conforming steel
I	0.13	0.28	2.35	0.013	0.0016	0.034	0.0025	0.0031				0.66									0.65	Conforming steel
J	0.09	0.52	1.76	0.015	0.0026	0.027	0.0031	0.0051					0.052								0.38	Conforming steel
K	0.06	0.34	1.38	0.012	0.0024	0.031	0.0026	0.0041						0.043							0.29	Conforming steel
L	0.05	0.29	1.16	0.029	0.0105	0.061	0.0031	0.0029							0.12						0.27	Conforming steel
M	0.07	0.18	1.36	0.016	0.0084	0.028	0.0045	0.0008									0.45				0.30	Conforming steel
N	0.09	0.40	1.81	0.022	0.0036	0.046	0.0039	0.0062								0.0025					0.39	Conforming steel
O	0.13	0.20	0.95	0.016	0.0027	0.033	0.0028	0.0041										0.0051			0.29	Conforming steel
P	0.15	0.61	1.17	0.008	0.0019	0.031	0.0042	0.0045											0.0063		0.35	Conforming steel
Q	0.10	0.36	1.85	0.011	0.0014	0.036	0.0028	0.0040												0.0095	0.41	Conforming steel
R	0.06	0.29	1.45	0.010	0.0008	0.024	0.0016	0.0028	0.56	1.84				0.026				0.0042			0.46	Conforming steel
S	0.09	0.47	1.64	0.008	0.0016	0.050	0.0034	0.0027		0.35	0.33	0.19				0.0008			0.0016		0.49	Conforming steel
T	0.05	0.52	1.32	0.004	0.0137	0.026	0.0029	0.0041		0.57			0.021	0.009	0.03					0.0041	0.31	Conforming steel
U	0.07	0.29	1.93	0.005	0.0026	0.045	0.0030	0.0028	0.23		0.28						0.26	0.0014			0.46	Conforming steel
<u>V</u>	<u>0.02</u>	0.18	1.35	0.009	0.0015	0.012	0.0034	0.0025													0.25	Comparative steel
<u>W</u>	<u>0.03</u>	0.25	0.78	0.013	0.0030	0.024	0.0031	0.0038		0.57	0.35		0.009						0.0021		0.27	Comparative steel

*1: Balance consists of Fe and inevitable impurities.

*2: Blank space indicates that the element is not intentionally added, including not only the case where the element is not contained (0 %) but also the case where the element is inevitably contained.

*3: Underline indicates outside the appropriate range.

[Table 2]

[0085]

Table 2

No.	Steel sample ID	Ceq	Thickness t (mm)	Ceq/t	Hot rolling conditions	Cooling conditions		Tempering conditions	Area ratio of void defects at thickness center position (%)	Area reduction ratio (%)	Yield stress (MPa)	Remarks
					Total rolling reduction ratio r_t in rolling passes under predetermined conditions (%)	Average cooling rate from 700 °C to 600 °C (°C/s)	$6000t^{-1.8}$	Tempering temperature (°C)				
1	A	0.27	63	0.0043	58	13.5	3.5	-	0	62	364	Example
2	B	0.25	35	0.0072	63	25.6	10.0	-	0	67	389	Example
3	C	0.23	50	0.0047	48	17.8	5.2	-	0	61	350	Example
4	D	0.49	185	0.0026	53	1.5	0.5	450	0.1	63	418	Example
5	E	0.37	143	0.0026	60	2.3	0.8	-	0.1	64	431	Example
6	F	0.44	120	0.0037	36	3.6	1.1	-	0.3	53	465	Example
7	G	0.27	45	0.0060	45	19.3	6.3	200	0	59	371	Example
8	H	0.56	210	0.0027	58	1.2	0.4	-	0.1	62	437	Example
9	I	0.65	230	0.0028	65	0.8	0.3	-	0.1	68	450	Example
10	J	0.38	135	0.0028	46	3.1	0.9	-	0.1	54	392	Example
11	K	0.29	82	0.0035	34	7.6	2.2	-	0.3	43	343	Example
12	L	0.27	76	0.0035	57	8.5	2.5	550	0	59	350	Example
13	M	0.30	65	0.0046	48	8.0	3.3	-	0.1	53	372	Example
14	N	0.39	151	0.0026	56	2.3	0.7	-	0.1	58	364	Example
15	O	0.29	60	0.0048	43	13.6	3.8	-	0.1	51	397	Example
16	P	0.35	115	0.0030	55	4.2	1.2	-	0.1	62	384	Example
17	Q	0.41	127	0.0032	36	3.5	1.0	-	0.3	40	436	Example
18	R	0.46	150	0 0031	42	2.4	0.7	620	0.2	56	454	Example
19	S	0.49	165	0.0030	51	1.8	0.6	-	0.1	59	448	Example
20	T	0.31	48	0.0065	49	18.5	5.6	-	0.1	53	437	Example

(continued)

No.	Steel sample ID	Ceq	Thickness t (mm)	Ceq/t	Hot rolling conditions	Cooling conditions		Tempering conditions	Area ratio of void defects at thickness center position (%)	Area reduction ratio (%)	Yield stress (MPa)	Remarks
					Total rolling reduction ratio r_t in rolling passes under predetermined conditions (%)	Average cooling rate from 700 °C to 600 °C (°C/s)	$6000t^{-1.8}$	Tempering temperature (°C)				
21	U	0.46	138	0.0034	61	2.9	0.8	-	0.1	62	451	Example
22	F	0.44	101	0.0044	41	5.3	1.5	-	0.1	65	481	Example
23	<u>V</u>	0.25	63	0.0039	45	15.5	3.5	-	0.1	49	<u>308</u>	Comparative Example
24	<u>W</u>	0.27	75	0.0036	52	8.8	2.5	-	0	55	<u>313</u>	Comparative Example
25	A	0.27	190	<u>0.0014</u>	56	1.5	0.5	360	0.1	62	<u>306</u>	Comparative Example
26	G	0.27	210	<u>0.0013</u>	40	1.3	0.4	-	0.2	58	<u>298</u>	Comparative Example
27	F	0.44	126	0.0035	<u>23</u>	3.6	1.0	-	<u>0.6</u>	24	436	Comparative Example
28	N	0.39	96	0 0041	<u>17</u>	5.4	1.6	470	<u>0.7</u>	20	435	Comparative Example
29	O	0.29	130	0.0022	53	<u>0.1</u>	0.9	-	0.1	58	<u>311</u>	Comparative Example
30	K	0.29	78	0.0037	46	<u>0.2</u>	2.4	-	0.1	53	<u>308</u>	Comparative Example
31	P	0.35	127	0.0027	60	3.4	1.0	<u>730</u>	0.1	62	<u>305</u>	Comparative Example
32	B	0.25	85	0.0030	48	8.1	2.0	<u>690</u>	0.1	59	<u>296</u>	Comparative Example

Underline indicates outside the appropriate range.

[0086] As shown in Table 2, the steel plate of each Example had excellent internal properties and high strength. Moreover, the steel plate of each Example was capable of being produced using a usual hot rolling line at low cost (i.e. with high productivity) with no need for special equipment.

[0087] On the other hand, the steel plate of each Comparative Example did not have sufficient internal properties and/or strength.

[0088] In detail, in Comparative Examples No. 23 and 24, the C content was below the appropriate range, so that the strength was insufficient.

[0089] In Comparative Examples No. 25 and 26, the relationship $Ceq/t \geq 0.0015$ was not satisfied, so that the strength was insufficient.

[0090] In Comparative Examples No. 27 and 28, the hot rolling conditions were not appropriate, so that the area ratio of void defects at the thickness center position was high and the internal properties were insufficient.

[0091] In Comparative Examples No. 29 and 30, the average cooling rate in the temperature range from 700 °C to 600 °C was excessively low, so that the strength was insufficient.

[0092] In Comparative Examples No. 31 and 32, the tempering temperature was excessively high, so that the strength was insufficient.

Claims

1. A steel plate comprising

a chemical composition containing, in mass%,
C: 0.04 % to 0.18 %,
Si: 0.03 % to 0.70 %,
Mn: 0.30 % to 2.50 %,
P: 0.030 % or less,
S: 0.0200 % or less,
Al: 0.001 % to 0.100 %,
O: 0.0100 % or less, and
N: 0.0100 % or less
with a balance consisting of Fe and inevitable impurities,
wherein Ceq defined by the following formula (1) and a thickness t in mm of the steel plate satisfy a relationship $Ceq/t \geq 0.0015$:

$$Ceq = [C] + [Mn]/6 + ([Cr] + [Mo] + [V])/5 + ([Cu] + [Ni])/15 \ldots \qquad (1)$$

where each bracketed element symbol in the formula (1) represents a content in mass% of a corresponding element in the chemical composition, and is set to 0 in the case where the element is not contained,
an area ratio of void defects at a thickness center position of the steel plate is 0.5 % or less, and
a yield stress is 325 MPa or more.

2. The steel plate according to claim 1, wherein the chemical composition further contains, in mass%, one or more selected from the group consisting of

Cu: 2.00 % or less,
Ni: 2.50 % or less,
Cr: 1.50 % or less,
Mo: 1.00 % or less,
Nb: 0.100 % or less,
Ti: 0.100 % or less,
V: 0.30 % or less,
B: 0.0100 % or less,
W: 0.50 % or less,
Ca: 0.0200 % or less,
Mg: 0.0200 % or less, and
REM: 0.0500 % or less.

3. A production method for the steel plate according to claim 1 or 2, the production method comprising:

preparing a slab having the chemical composition according to claim 1 or 2;
hot rolling the slab to obtain a hot-rolled steel plate; and
cooling the hot-rolled steel plate,
wherein a total rolling reduction ratio in rolling passes that satisfy the following (a) and (b) in the hot rolling is more than 30 %:

(a) a temperature at a thickness center position of the slab: 700 °C or more, and
(b) a temperature difference between a surface and the thickness center position of the slab: 100 °C or more, and

in the cooling, an average cooling rate in °C/s in a temperature range from 700 °C to 600 °C at a position of 1/4 of a thickness of the hot-rolled steel plate is $6000t^{-1.8}$ or more, where t is the thickness in mm of the hot-rolled steel plate.

4. The production method according to claim 3, further comprising
subjecting the hot-rolled steel plate to a tempering treatment at a tempering temperature of 650 °C or less, after the cooling.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/035525

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/00(2006.01)i; ***C21D 8/02***(2006.01)i; ***C22C 38/06***(2006.01)i; ***C22C 38/58***(2006.01)i
FI: C22C38/00 301A; C22C38/06; C22C38/58; C21D8/02 A

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; C21D8/02

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2007-302908 A (SUMITOMO METAL INDUSTRIES, LTD.) 22 November 2007 (2007-11-22) claims 1-4, paragraphs [0042]-[0071], [0104]-[0107]	1-2
A		3-4
X	WO 2021/182618 A1 (NIPPON STEEL CORP.) 16 September 2021 (2021-09-16) claims 1-5, paragraphs [0018]-[0042], [0056]-[0078]	2
A		1, 3-4

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

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"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
28 October 2022	**29 November 2022**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/035525

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2007-302908 A	22 November 2007	(Family: none)	
WO 2021/182618 A1	16 September 2021	CN 115244205 A KR 10-2022-0133985 A	

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

REFERENCES CITED IN THE DESCRIPTION

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- JP H669569 B **[0006] [0008]**
- JP S5974220 A **[0007] [0008]**