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(54) THICK STEEL SHEET AND PRODUCTION METHOD THEREFOR

(57) An object is to provide a steel plate having excellent deformability in the central portion in the thickness direction and a method for manufacturing the steel plate.

A steel plate having a chemical composition containing, by mass%, C: 0.01% to 0.15%, Si: 0.01% to 1.00%, Mn: 0.10% to 2.00%, P: 0.010% or less, S: 0.0050% or less, Al: 0.002% to 0.100%, Ni: 5.0% to 10.0%, N: 0.0010% to 0.0080%, and with a balance being Fe and incidental impurities and a percentage reduction of area of 30% or more in a tensile test in the thickness direction performed on the central portion in the thickness direction.

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Description

Technical Field

[0001] The present invention relates to a steel plate which can preferably be used as structural steel used in a cryogenic environment for, for example, a liquefied gas storage tank and to a method for manufacturing the steel plate. In particular, the present invention relates to a steel plate which is excellent in terms of mechanical properties and, especially, deformability in the central portion in the thickness direction and to a method for manufacturing the steel plate. Here, in the present invention, the term "steel plate" denotes a steel plate having a thickness of 6 mm to 80 mm.

Background Art

[0002] A steel plate which is used in a cryogenic environment for, for example, a liquefied gas storage tank is required to have not only satisfactory strength as a steel plate but also toughness at cryogenic temperatures. For example, in the case where a steel plate is used for a liquefied natural gas (LNG) storage tank, it is necessary to achieve excellent toughness at temperatures equal to or lower than -164°C, which is the boiling point of LNG. In the case where the steel material is poor in terms of low-temperature toughness, there is a risk in that it is not possible to maintain the safety of a structure used as a cryogenic storage tank. Therefore, the steel plate to be used is strongly required to have improved low-temperature toughness. In response to such a requirement, a Ni-containing steel plate having a retained austenite microstructure such as a 7% Ni steel plate or a 9% Ni steel plate, in which embrittlement does not occur at cryogenic temperatures, is used.

[0003] To achieve excellent low-temperature toughness, Patent Literature 1 discloses a method for stabilizing a retained austenite microstructure, which tends to be unstable at low temperatures, by decreasing the grain size of untransformed austenite and by generating lattice defects to decrease the Mf temperature. In addition, Patent Literature 2 discloses steel for cryogenic temperatures having an excellent CTOD property in a welded heat affected zone including a weld toe obtained by adjusting the contents of Si, Al, and N and by controlling the Fe content in residue after a simulated thermal recycle test has been performed. In addition, Patent Literature 3 discloses a steel plate whose yield strength, tensile strength, and toughness at cryogenic temperatures are equal to or higher than predetermined values and which is excellent in terms of safety against fracturing and a method for manufacturing the steel plate.

Citation List

Patent Literature

[0004]

PTL 1: International Publication No. 2007/034576
PTL 2: International Publication No. 2007/080646
PTL 3: Japanese Unexamined Patent Application Publication No. 2011-241419

Summary of Invention

Technical Problem

[0005] For example, in the case of a structure used as a cryogenic storage tank which is used in a cryogenic environment, a T-shaped joint is formed around a weld zone between a bottom panel and a side panel. Since stress applied to a steel material increases with an increase in the size of the tank, the steel material is required to have satisfactory deformability in the thickness direction from the viewpoint of safety. Therefore, achieving satisfactory deformability in the central portion in the thickness direction, in which such a property tends to be particularly poor, is required.

[0006] However, in the case of conventional Ni-containing steel plates including those according to Patent Literature 1 to Patent Literature 3, since no consideration is given to deformability in the central portion in the thickness direction, it may be said that deformability in the central portion in the thickness direction is not sufficiently achieved.

[0007] The present invention has been completed in view of such a problem, and an object of the present invention is to provide a steel plate having excellent deformability in the central portion in the thickness direction and a method for manufacturing the steel plate.

Solution to Problem

[0008] To achieve the object described above, the present inventors diligently conducted investigations regarding the chemical composition and manufacturing method of a Ni-containing steel plate which can preferably be used as structural steel for use in a cryogenic environment and, as a result, established the following knowledge.

1. By controlling a percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction, it is possible to improve the deformability of the central portion in the thickness direction.
2. In finish rolling in a hot rolling process, by controlling a reduction ratio to be 3 or more and by controlling a rolling shape factor to be 0.7 or more in each of at least two rolling passes of the final three rolling passes, since it is possible to inhibit the generation of casting defects and coarse grains in the central portion in the thickness direction to obtain a homogeneous grain size distribution throughout a steel plate, it is possible to improve a tensile property in the thickness direction (percentage reduction of area) in the central portion in the thickness direction.
3. Regarding the tensile property in the thickness direction (percentage reduction of area) in a tensile test in the thickness direction performed on the central portion in the thickness direction, the percentage reduction of area decreases with an increase in the number of casting defects and coarse MnS particles having a major axis of 100 μm or more in the central portion in the thickness direction. In addition, the percentage reduction of area decreases with an increase in the number of coarse prior austenite grains having a circle-equivalent diameter of 100 μm or more. This is because, since stress concentration occurs at the positions of casting defects, coarse MnS particles, and coarse prior austenite grains, such positions may become fracture origins.
4. By controlling the S content to be 0.0050% or less and by decreasing the amount of central segregation through soft reduction when continuous casting is performed, since it is possible to decrease the number of casting defects and coarse MnS particles, it is possible to further improve the tensile property in the thickness direction (percentage reduction of area) in the central portion in the thickness direction.

[0009] The present invention has been completed by further conducting investigations into the knowledge described above, and the subject matter of the present invention is as follows.

[1] A steel plate having a chemical composition containing, by mass%, C: 0.01% to 0.15%, Si: 0.01% to 1.00%, Mn: 0.10% to 2.00%, P: 0.010% or less, S: 0.0050% or less, Al: 0.002% to 0.100%, Ni: 5.0% to 10.0%, N: 0.0010% to 0.0080%, and with a balance being Fe and incidental impurities, and a percentage reduction of area of 30% or more in a tensile test in a thickness direction performed on a central portion in the thickness direction.
[2] The steel plate according to [1], wherein the chemical composition further contains, by mass%, one, two, or more selected from Cr: 0.01% to 1.50%, Mo: 0.03% to 1.0%, Nb: 0.001% to 0.030%, V: 0.01% to 0.10%, Ti: 0.003% to 0.050%, B: 0.0003% to 0.0100%, and Cu: 0.01% to 1.00%.
[3] The steel plate according to [1] or [2], wherein the chemical composition further contains, by mass%, one, two, or more selected from Sn: 0.01% to 0.30%, Sb: 0.01% to 0.30%, W: 0% (not inclusive) to 2.00%, Co: 0% (not inclusive) to 2.00%, Ca: 0.0005% to 0.0050%, Mg: 0.0005% to 0.0050%, Zr: 0.0005% to 0.0050%, and REM: 0.0010% to 0.0100%.
[4] A method for manufacturing a steel plate, the method comprising heating a slab having the chemical composition according to any one of [1] to [3] to a temperature of 1000°C or higher and 1300°C or lower and performing hot rolling on the heated slab in such a manner that finish rolling is performed with a reduction ratio of 3 or more and that each of at least two rolling passes of final three rolling passes is performed with a rolling shape factor of 0.7 or more.

Advantageous Effects of Invention

[0010] According to the present invention, it is possible to obtain a steel plate having excellent deformability in the central portion in the thickness direction. The steel plate according to the present invention contributes significantly to improving the safety of steel structures used in a cryogenic environment such as a liquefied gas storage tank, which has a significant effect on the industry. Description of Embodiments

[0011] Hereafter, embodiments of the present invention will be described. Here, the present invention is not limited to the embodiments below.

[0012] First, the chemical composition of the steel plate according to the present invention and the reasons for the limitations on the chemical composition will be described. Here, % used when describing the chemical composition denotes mass%, unless otherwise denoted.

C: 0.01% to 0.15%

[0013] C is effective for increasing strength, and it is necessary that the C content be 0.01% or more to realize such an effect. It is preferable that the C content be 0.03% or more. On the other hand, in the case where the C content is more than 0.15%, since C is segregated in the central portion in the thickness direction, the precipitation of Cr carbides and Nb-, V-, and Ti-based carbides is excessively promoted, which results in a deterioration in low-temperature toughness and percentage reduction of area. Therefore, the C content is set to be 0.15% or less. It is preferable that the C content be 0.10% or less.

Si: 0.01% to 1.00%

[0014] Since Si functions as a deoxidizing agent, Si is necessary for a steel-making process. In addition, Si is effective for increasing the strength of a steel plate through solid solution strengthening by forming a solid solution in steel. To realize such effects, it is necessary that the Si content be 0.01% or more. On the other hand, in the case where the Si content is more than 1.00%, there is a deterioration in weldability and surface quality. Therefore, the Si content is set to be 1.00% or less. It is preferable that the Si content be 0.5% or less or more preferably 0.3% or less.

Mn: 0.10% to 2.00%

[0015] Mn is an element which is effective for increasing strength by improving the hardenability of a steel plate. To realize such an effect, it is necessary that the Mn content be 0.10% or more. It is preferable that the Mn content be 0.40% or more. On the other hand, in the case where the Mn content is more than 2.00%, since central segregation is promoted, there is a deterioration in cryogenic toughness and percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction, and stress corrosion cracking occurs. In addition, in the central portion in the thickness direction, the formation of coarse MnS particles having a major axis of 100 μm or more, which become fracture origins, is promoted, and there is thus a significant deterioration in percentage reduction of area in a tensile test in the thickness direction. Therefore, the Mn content is set to be 2.00% or less. It is preferable that the Mn content be 1.00% or less.

P: 0.010% or less

[0016] In the case where the P content is more than 0.010%, since P causes a deterioration in grain-boundary strength as a result of being segregated at grain boundaries, thereby becoming a fracture origin, there is a deterioration in percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction. Therefore, it is preferable that the P content be as small as possible, and the P content is set to be 0.010% or less.

S: 0.0050% or less

[0017] S forms MnS in steel, thereby causing a significant deterioration in low-temperature toughness and percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction. Therefore, it is preferable that the S content be as small as possible, and the S content is set to be 0.0050% or less. It is preferable that the S content be 0.0020% or less.

Al: 0.002% to 0.100%

[0018] Since Al functions as a deoxidizing agent, Al is most commonly used in a deoxidizing process performed on molten steel. In addition, by fixing solid solution N in steel to form AlN, Al is effective for inhibiting a deterioration in toughness by decreasing the amount of solid solution N. To realize such effects, it is necessary that the Al content be 0.002% or more. It is preferable that the Al content be 0.010% or more or more preferably 0.020% or more. On the other hand, in the case where the Al content is more than 0.100%, since Al is diffused in a weld metal when welding is performed, there is a deterioration in the toughness of the weld metal. Therefore, the Al content is set to be 0.100% or less. It is preferable that the Al content be 0.070% or less or more preferably 0.060% or less.

Ni: 5.0% to 10.0%

[0019] Ni is an element which increases the strength of a steel plate and which is significantly effective for improving the low-temperature toughness of a steel plate by stabilizing retained austenite. Since Ni is an expensive element, steel plate cost increases significantly with an increase in the Ni content. Therefore, the Ni content is set to be 10.0% or less.

On the other hand, in the case where the Ni content is less than 5.0%, there is a deterioration in the strength of a steel plate, and it is not possible to form stable retained austenite at low temperatures, which results in a deterioration in the low-temperature toughness and strength of a steel plate. Therefore, the Ni content is set to be 5.0% or more. It is preferable that the Ni content be 6.0% to 9.0%.

N: 0.0010% to 0.0080%

[0020] Since N is an austenite-stabilizing element, N is an element which is effective for improving cryogenic toughness. In addition, by combining with Nb, V, and Ti to be finely precipitated in the form of nitrides or carbonitrides, which function as trap sites of diffusive hydrogen, N is effective for inhibiting stress corrosion cracking. To realize such effects, it is necessary that the N content be 0.0010% or more. It is preferable that the N content be 0.0020% or more. On the other hand, in the case where the N content is more than 0.0080%, since the formation of an excessive number of nitrides or carbonitrides is promoted, there is a decrease in the amount of solid solution elements, which results in a deterioration in not only corrosion resistance but also toughness and percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction. Therefore, the N content is set to be 0.0080% or less. It is preferable that the N content be 0.0060% or less.

[0021] In the present invention, to further improve strength and low-temperature toughness, one, two, or more selected from Cr: 0.01% to 1.50%, Mo: 0.03% to 1.0%, Nb: 0.001% to 0.030%, V: 0.01% to 0.10%, Ti: 0.003% to 0.050%, B: 0.0003% to 0.0100%, and Cu: 0.01% to 1.00% may be added as needed in addition to the indispensable constituents described above.

Cr: 0.01% to 1.50%

[0022] Cr is an element which is effective for increasing strength. To realize such an effect, the Cr content is set to be 0.01% or more, in the case where Cr is added. On the other hand, since Cr may be precipitated in the form of nitrides, carbides, carbonitrides, and the like when rolling is performed, such precipitates become origins at which corrosion and fracturing occur, which results in a deterioration in low-temperature toughness. Therefore, in the case where Cr is added, the Cr content is set to be 1.50% or less. It is preferable that the Cr content be 1.00% or less.

Mo: 0.03% to 1.0%

[0023] Mo is an element which is effective for decreasing the temper embrittlement susceptibility of a steel plate and for increasing the strength of a steel plate without causing a deterioration in low-temperature toughness. To realize such effects, the Mo content is set to be 0.03% or more, in the case where Mo is added. It is preferable that the Mo content be more than 0.05%. On the other hand, in the case where the Mo content is more than 1.0%, there is a deterioration in low-temperature toughness. Therefore, in the case where Mo is added, it is preferable that the Mo content be 1.0% or less or more preferably 0.30% or less.

Nb: 0.001% to 0.030%

[0024] Nb is an element which is effective for improving the strength of a steel plate. To realize such an effect, the Nb content is set to be 0.001% or more, in the case where Nb is added. It is preferable that the Nb content be 0.005% or more or more preferably 0.007% or more. On the other hand, in the case where the Nb content is more than 0.030%, since coarse carbonitrides are precipitated, such precipitates become fracture origins, which may result in a deterioration in a tensile property in the thickness direction in the central portion in the thickness direction. In addition, there is coarsening of the precipitate, which may result in a deterioration in the toughness of a base material. Therefore, in the case where Nb is added, the Nb content is set to be 0.030% or less. It is preferable that the Nb content be 0.025% or less or more preferably 0.022% or less.

V: 0.01% to 0.10%

[0025] V is an element which is effective for improving the strength of a steel plate. To realize such an effect, the V content is set to be 0.01% or more, in the case where V is added. It is preferable that the V content be 0.02% or more or more preferably 0.03% or more. On the other hand, in the case where the V content is more than 0.10%, since coarse carbonitrides are precipitated, such carbonitrides may become fracture origins. In addition, there is coarsening of the precipitates, which may result in a deterioration in the toughness of a base material. Therefore, in the case where V is added, the V content is set to be 0.10% or less. It is preferable that the V content be 0.09% or less or more preferably 0.08% or less.

Ti: 0.003% to 0.050%

[0026] Ti is an element which is effective for improving the strength of a steel plate as a result of being precipitated in the form of nitrides or carbonitrides. To realize such an effect, the Ti content is set to be 0.003% or more, in the case where Ti is added. It is preferable that the Ti content be 0.005% or more or more preferably 0.007% or more. On the other hand, in the case where the Ti content is more than 0.050%, there is coarsening of the precipitates, which may result in a deterioration in the toughness of a base metal. In addition, since coarse carbonitrides are precipitated, such precipitates may become fracture origins. Therefore, in the case where Ti is added, the Ti content is set to be 0.050% or less. It is preferable that the Ti content be 0.035% or less or more preferably 0.032% or less.

B: 0.0003% to 0.0100%

[0027] B is an element which is effective for improving the strength of a base material. To realize such an effect, the B content be 0.0003% or more, in the case where B is added. On the other hand, in the case where the B content is more than 0.0100%, since coarse B-based precipitates are formed, there is a deterioration in toughness. Therefore, in the case where B is added, the B content is set to be 0.0100% or less. It is preferable that the B content be 0.0030% or less.

Cu: 0.01% to 1.00%

[0028] Cu is an element which is effective for improving the strength of a steel plate because of an improvement in hardenability. To realize such an effect, the Cu content is set to be 0.01% or more, in the case where Cu is added. On the other hand, in the case where the Cu content is more than 1.00%, there is a deterioration in the low-temperature toughness of a steel plate, and there may be a deterioration in the surface quality of a steel slab which has been cast. Therefore, in the case where Cu is added, the Cu content is set to be 1.00% or less. It is preferable that the Cu content be 0.30% or less.

[0029] Moreover, in the present invention, one, two, or more selected from Sn: 0.01% to 0.30%, Sb: 0.01% to 0.30%, W: 0% (not inclusive) to 2.00%, Co: 0% (not inclusive) to 2.00%, Ca: 0.0005% to 0.0050%, Mg: 0.0005% to 0.0050%, Zr: 0.0005% to 0.0050%, and REM: 0.0010% to 0.0100% may be added as needed.

Sn: 0.01% to 0.30%

[0030] Sn is an element which is effective for improving corrosion resistance. Although such an element is effective, even in the case where its content is low, the Sn content is set to be 0.01% or more, in the case where Sn is added. However, in the case where the Sn content is high, there is a deterioration in weldability and toughness, and there is also a disadvantage from a cost point of view. Therefore, in the case where Sn is added, the Sn content is set to be 0.30% or less. It is preferable that the Sn content be 0.25% or less.

Sb: 0.01% to 0.30%

[0031] Sb is, like Sn, an element which is effective for improving corrosion resistance. Although such an element is effective, even in the case where its content is low, the Sb content is set to be 0.01% or more, in the case where Sb is added. However, in the case where the Sb content is high, there is a deterioration in weldability and toughness, and there is also a disadvantage from a cost point of view. Therefore, in the case where Sb is added, the Sb content is set to be 0.30% or less. It is preferable that the Sb content be 0.25% or less.

W: 0% (not inclusive) to 2.00%

[0032] W is, like Sn and Sb, an element which is effective for improving corrosion resistance. Since such an element is effective, even in the case where its content is low, W may be added in an amount of more than 0%. However, in the case where the W content is high, there is a deterioration in weldability and toughness, and there is also a disadvantage from a cost point of view. Therefore, in the case where W is added, the W content is set to be 2.00% or less. It is preferable that the W content be 0.50% or less.

Co: 0 (not inclusive) to 2.00%

[0033] Co is, like Sn, Sb, and W, an element which is effective for improving corrosion resistance. Since such an element is effective, even in the case where its content is low, Co may be added in an amount of more than 0%. It is preferable that the Co content be 0.10% or more. However, in the case where the Co content is high, there is a deterioration

in weldability and toughness, and there is also a disadvantage from a cost point of view. Therefore, in the case where Co is added, the Co content is set to be 2.00% or less. It is preferable that the Co content be 1.50% or less.

Ca: 0.0005% to 0.0050%

[0034] Since Ca is an element which is effective for the morphological control of inclusions such as MnS, Ca may be added as needed. The expression "morphological control of inclusions" denotes a case where elongated sulfide-based inclusions are made into granular inclusions. Through such morphological control of inclusions, it is possible to improve a tensile property in the thickness direction, toughness, and sulfide stress corrosion cracking resistance in the central portion in the thickness direction. To realize such effects, the Ca content is set to be 0.0005% or more, in the case where Ca is added. It is preferable that the Ca content be 0.0010% or more. On the other hand, in the case where the Ca content is high, since there is an increase in the amounts of nonmetallic inclusions, there may be a deterioration, rather than an improvement, in a tensile property in the thickness direction in the central portion in the thickness direction. Therefore, in the case where Ca is added, the Ca content is set to be 0.0050% or less. It is preferable that the Ca content be 0.0040% or less.

Mg: 0.0005% to 0.0050%

[0035] Since Mg is, like Ca, an element which is effective for the morphological control of inclusions such as MnS, Mg may be added as needed. Through such morphological control of inclusions, it is possible to improve a tensile property in the thickness direction, toughness, and sulfide stress corrosion cracking resistance in the central portion in the thickness direction. To realize such effects, the Mg content is set to be 0.0005% or more, in the case where Mg is added. It is preferable that the Mg content be 0.0010% or more. On the other hand, in the case where the Mg content is high, since there is an increase in the number of nonmetallic inclusions, there may be a deterioration, rather than an improvement, in a tensile property in the thickness direction in the central portion in the thickness direction. Therefore, in the case where Mg is added, the Mg content is set to be 0.0050% or less. It is preferable that the Mg content be 0.0040% or less.

Zr: 0.0005% to 0.0050%

[0036] Since Zr is, like Ca and Mg, an element which is effective for the morphological control of inclusions such as MnS, Zr may be added as needed. Through such morphological control of inclusions, it is possible to improve a tensile property in the thickness direction, toughness, and sulfide stress corrosion cracking resistance in the central portion in the thickness direction. To realize such effects, the Zr content is set to be 0.0005% or more. It is preferable that the Zr content be 0.0010% or more. On the other hand, in the case where the Zr content is high, since there is an increase in the number of nonmetallic inclusions, there may be a deterioration, rather than an improvement, in a tensile property in the thickness direction in the central portion in the thickness direction. Therefore, in the case where Zr is added, the Zr content is set to be 0.0050% or less. It is preferable that the Zr content be 0.0040% or less.

REM: 0.0010% to 0.0100%

[0037] Since REM are, like Ca, Mg, and Zr, elements which are effective for the morphological control of inclusions such as MnS, REM may be added as needed. Through such morphological control of inclusions, it is possible to improve a tensile property in the thickness direction, toughness, and sulfide stress corrosion cracking resistance in the central portion in the thickness direction. To realize such effects, the REM content is set to be 0.0010% or more. It is preferable that the REM content be 0.0020% or more. On the other hand, in the case where the REM content is high, since there is an increase in the number of nonmetallic inclusions, there may be a deterioration, rather than an improvement, in a tensile property in the thickness direction in the central portion in the thickness direction. Therefore, in the case where REM are added, the REM content is set to be 0.0100% or less.

[0038] Here, the remainder is Fe and incidental impurities.

[0039] In addition, the steel plate according to the present invention has deformability represented by a percentage reduction of area of 30% or more in a tensile test in the thickness direction performed on the central portion in the thickness direction. Here, the term "percentage reduction of area" denotes, when a tensile test is performed, the ratio ($\Delta S/S$ (%)) of the amount of reduction in the cross-sectional area ΔS of a test specimen after the test to the cross-sectional area S of the test specimen before the test. By controlling the percentage reduction of area to be 30% or more, it is possible to achieve satisfactory deformability in the central portion in the thickness direction. In the present invention, it is preferable that the percentage reduction of area be 35% or more. Here, it is possible to achieve the percentage reduction of area according to the present invention by controlling the soft reduction condition applied for casting and/or the conditions applied for finish rolling described below.

[0040] In addition, in the present invention, in the central portion in the thickness direction, it is preferable that the number of MnS particles having a major axis of 100 μm or more be 10 pieces/mm^2 or less and that prior austenite grains have a circle-equivalent diameter of less than 100 μm. This is because, since stress concentration occurs at the positions of casting defects, coarse MnS particles, and coarse prior austenite grains, such positions may become fracture origins. Here, it is possible to form the desired MnS by controlling the soft reduction condition applied for continuous casting described below.

[0041] In addition, in the present invention, the expression "central portion in the thickness direction" denotes a position located at 1/2 of the thickness, and the percentage reduction of area and the sizes of MnS particles and prior austenite grains are determined by using the determination methods described in EXAMPLE below.

[0042] Hereafter, the manufacturing conditions according to the present invention will be described. Here, in the description below, the term "temperature (°C)" denotes the temperature in the central portion in the thickness direction.

[0043] The method for manufacturing the steel plate according to the present invention includes heating a slab having the desired chemical composition to a temperature of 1000°C or higher and 1300°C or lower and performing hot rolling on the heated slab in such a manner that finish rolling is performed with a reduction ratio of 3 or more and that each of at least two rolling passes of the final three rolling passes is performed with a rolling shape factor of 0.7 or more.

Reheating temperature of steel material: 1000°C or higher and 1300°C or lower

[0044] The steel material is reheated to dissolve precipitates in a microstructure and to homogenize a grain size distribution and the like, and the reheating temperature is set to be 1000°C or higher and 1300°C or lower. In the case where the reheating temperature is lower than 1000°C, since precipitates such as AlN are not sufficiently dissolved, and since there is coarsening of such precipitates when reheating is performed, such precipitates become fracture origins, which results in the desired percentage reduction of area in a tensile test in the thickness direction not being achieved. On the other hand, in the case where the reheating temperature is higher than 1300°C, there is a deterioration in toughness due to an increase in grain size, and there is an increase in manufacturing costs. Therefore, the reheating temperature is set to be 1300°C or lower. It is preferable that the reheating temperature be 1250°C or lower or more preferably 1200°C or lower. Here, it is preferable that the reheating time be 1 hour to 10 hours.

Reduction ratio in finish rolling: 3 or more

[0045] When finish rolling in a hot rolling process is performed, by controlling the reduction ratio ((slab thickness)/(final thickness)) to be 3 or more, it is possible to homogenize a grain size distribution by promoting recrystallization, and it is possible to render casting defects such as minute voids known as porosity harmless by eliminating the voids through pressure compression. Moreover, since it is possible to form the desired microstructure in the hot rolled steel plate by inhibiting the central segregation of Mn, P, S, and the like, it is possible to achieve the desired tensile property in the thickness direction. In the case where hot rolling is performed with a reduction ratio of less than 3, since it is not possible to form the desired microstructure, for example, due to coarse grains remaining in the microstructure and due to the above-described casting defects and central segregation being insufficiently rendered harmless, it is not possible to achieve the desired percentage reduction of area in a tensile test in the thickness direction. Therefore, the reduction ratio is set to be 3 or more. It is preferable that the reduction ratio be 4 or more or more preferably 5 or more.

Rolling shape factor in each of at least two rolling passes of final three rolling passes in finish rolling: 0.7 or more

[0046] By performing at least two rolling passes of three final rolling passes, in which the material properties are finally determined, with a rolling shape factor of 0.7 or more, it is possible to render casting defects harmless with certainty, and it is possible to homogenize a grain size distribution by inhibiting coarse grains from remaining in the whole steel plate, and in particular, in the central portion in the thickness direction. As a result, there is an improvement in percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction. Here, the term "rolling shape factor (ld/h_m)" denotes {contact length between rolling roll and steel plate (roll contact arc length: ld)}/{average thickness calculated from thickness on the roll entry side and thickness on the roll exit side: h_m}, which is calculated by using equation (1).

$$ld/h_m = \{R(h_i - h_o)\}^{1/2}/\{(h_i + 2h_o)/3\} \quad \cdots \quad (1)$$

Here,

R: roll radius of each rolling pass

h_i: thickness on the entry side of each rolling pass
h_o: thickness on the exit side of each rolling pass

[0047] In the case where the number of passes having a rolling shape factor of 0.7 or more is less than 2, since it is not possible to form the desired microstructure, for example, due to coarse grains remaining in the microstructure and due to the above-described casting defects being insufficiently rendered harmless, it is not possible to achieve the desired percentage reduction of area in a tensile test in the thickness direction performed on the central portion in the thickness direction. Therefore, the number of rolling passes having a rolling shape factor of 0.7 or more is set to be at least 2. Here, to increase the rolling shape factor, it is sufficient that the diameters of rolling rolls be increased or that the rolling reduction be increased.

[0048] Although there is no particular limitation on the manufacturing conditions other than those described above, it is preferable that the following conditions be applied.

Soft reduction in casting

[0049] In the present invention, it is preferable that slab be subjected to soft reduction when continuous casting is performed. In the present invention, by performing soft reduction, it is possible to further inhibit coarse MnS particles having a major axis of 100 μm or more and coarse prior austenite grains having a circle-equivalent diameter of 100 μm or more from remaining in the central portion in the thickness direction. Regarding the specific condition applied for soft reduction, it is preferable that the reduction gradient be 0.1 mm/m or more on the upstream side of the final solidification position of a slab.

Cooling start temperature after hot rolling

[0050] In the present invention, there is no particular limitation on the cooling start temperature after hot rolling has been performed, and it is preferable that the cooling start temperature be 1000°C or lower and 500°C or higher.

Cooling method after hot rolling

[0051] In the present invention, there is no particular limitation on the cooling method used after hot rolling has been performed, and an appropriate method such as an air cooling method or a water cooling method may be used. To achieve necessary properties such as strength and low-temperature toughness, water cooling such as spray cooling, mist cooling, or laminar cooling may be performed after hot rolling has been performed.

Heat treatment after hot rolling

[0052] In the present invention, although a final product may be obtained by performing cooling after hot rolling has been performed, it is preferable that a heat treatment be further performed to achieve necessary properties such as low-temperature toughness. As a heating treatment, it is preferable that a tempering treatment be performed after hot rolling has been performed. In addition, a quenching-tempering treatment, in which a quenching treatment is also performed before a tempering treatment is performed, may be performed. In addition, an inter-critical quenching-tempering treatment, in which a tempering treatment is performed after an inter-critical quenching has been performed, may be performed. Moreover, a quenching-inter-critical quenching-tempering treatment, in which an inter-critical quenching is performed between a quenching treatment and a tempering treatment, may be performed. It is preferable that at least one of the manufacturing treatments described above be performed.

[0053] It is preferable that the quenching temperature be equal to or higher than the AC_3 transformation temperature and 1000°C or lower. It is preferable that the inter-critical quenching temperature be equal to or higher than the Ac_1 transformation temperature and lower than the Ac_3 transformation temperature. It is preferable that the tempering temperature be 500°C to 650°C.

[0054] Here, the Ac_1 transformation temperature and the Ac_3 transformation temperature are respectively calculated by using equations (2) and (3) below.

$$Ac_1\ (°C) = 750.8 - 26.6C + 17.6Si - 11.6Mn - 22.9Cu - 23Ni + 24.1Cr + 22.5Mo - 39.7V - 5.7Ti + 232.4Nb - 169.4Al \quad \cdots (2)$$

$$Ac_3\ (°C) = 937.2 - 436.5C + 56Si - 19.7Mn - 16.3Cu - 26.6Ni - 4.9Cr + 38.1Mo + 124.8V + 136.3Ti - 19.1Nb + 198.4Al \cdots (3)$$

[0055] Here, each of the atomic symbols in equations (2) and (3) above denotes the content (mass%) of the corresponding element and is assigned a value of 0 in the case where the corresponding element is not contained.

EXAMPLES

[0056] Molten steels having the chemical compositions given in Table 1 were prepared and made into slabs, and the slabs were then made into steel plates having a thickness of 12 mm to 70 mm under the manufacturing conditions given in Table 2. Here, regarding soft reduction, the reduction gradient was 0.20 mm/m in the case of sample Nos. 1 to 30, 0.07 mm/m in the case of sample No. 31, and 0.10 mm/m in the case of sample No. 32.

[0057] The obtained steel plates were subjected to the tests described below.

(Mechanical properties in thickness direction)

[0058] Regarding tensile properties, the steel plate was processed into a test specimen having the shape of Type A so that the thickness direction of the steel plate was the tensile direction, and a tensile test was performed in accordance with JIS G 3199. Regarding low-temperature toughness, a test specimen which had been taken so that the thickness direction of the steel plate was the tensile direction was cooled to a temperature of -196°C in liquefied nitrogen, and then subjected to a Charpy impact test in accordance with JIS Z 2242 to derive absorbed energy vE_{-196} at a temperature of -196°C.

[0059] In the present invention, a case of a yield strength (YS) of 585 MPa or more, a tensile strength (TS) of 690 MPa or more, a percentage reduction of area after breaking (the ratio of the amount of reduction in the cross-sectional area ΔS of the test specimen after a tensile test to the cross-sectional area S of the test specimen before the tensile test) of 30% or more, and a vE_{-196} of 34 J or more was judged as satisfactory.

(Microstructure)

[0060] A test specimen for microstructure observation was taken from the obtained steel plate so that a position located at 1/2 of the thickness was an observation position. The test specimen was embedded in a resin so that the cross section perpendicular to the rolling direction was an observation surface and subjected to mirror polishing. Subsequently, the test specimen was etched in picric acid and observed by using a SEM at a magnification of 200 times to obtain the SEM image of a microstructure at the position located at 1/2 of the thickness. The photographic images obtained in five fields of view were analyzed by using an image analyzer to derive the number density of MnS particles having a major axis of 100 μm or more and the maximum value of the circle-equivalent diameter of prior austenite grains.

[0061] The results obtained as described above are given in Table 2.

[Table 1]

Steel	Chemical Composition (mass%)																					Ac_1 Transformation Temperature	Ac_3 Transformation Temperature
Code	C	Si	Mn	P	S	Al	Ni	N	Ti	Cr	B	Cu	Mo	V	W	Nb	Sn	Sb	Co	Mg	Ca	Zr	REM		
A	0.08	0.22	0.69	0.001	0.0019	0.027	8.1	0.0019																554	691
B	0.05	0.23	0.50	0.007	0.0011	0.030	9.5	0.0036																524	672
C	0.02	0.43	1.65	0.001	0.0004	0.020	9.3	0.0024																521	677
D	0.05	0.02	0.85	0.003	0.0006	0.035	7.1	0.0055	0.011												0.0006			571	719
E	0.07	0.10	0.18	0.002	0.0009	0.026	6.6	0.0035				0.25											0.0021	587	734
F	0.12	0.43	1.06	0.006	0.0012	0.031	9.3	0.0024												0.0023				524	647
G	0.06	0.08	0.85	0.002	0.0004	0.036	5.2	0.0026		0.50			0.13											630	770
H	0.05	0.06	0.55	0.009	0.0005	0.022	7.6	0.0029			0.0007											0.0009		566	710
I	0.04	0.04	0.91	0.005	0.0007	0.022	8.2	0.0026						0.05										546	697
J	0.03	0.03	0.25	0.002	0.0003	0.021	9.1	0.0018							0.45									535	683
K	0.04	0.05	0.85	0.003	0.0006	0.020	6.7	0.0031																583	732
L	0.11	0.07	0.41	0.005	0.0005	0.032	8.9	0.0021								0.011								537	654
M	0.02	0.11	0.71	0.006	0.0009	0.021	9.3	0.0024									0.03							527	677

(continued)

Steel	Chemical Composition (mass%)																							Ac_1 Transformation Temperature	Ac_3 Transformation Temperature
Code	C	Si	Mn	P	S	Al	Ni	N	Ti	Cr	B	Cu	Mo	V	W	Nb	Sn	Sb	Co	Mg	Ca	Zr	REM		
N	0.05	0.07	0.61	0.003	0.0006	0.033	7.1	0.0055										0.10						575	725
O	0.04	0.11	0.85	0.007	0.0007	0.010	8.4	0.0024											0.10					547	688
P	0.45	0.03	0.85	0.003	0.0012	0.022	7.1	0.0026																562	541
Q	0.11	0.12	3.50	0.007	0.0010	0.025	5.5	0.0044		0.21			0.19											588	692
R	0.12	0.43	1.65	0.050	0.0012	0.025	5.5	0.0026				0.31									0.0012			598	730
S	0.07	0.23	0.91	0.009	0.0100	0.036	9.3	0.0035						0.06						0.0011				520	669
T	0.04	0.43	0.25	0.006	0.0012	0.031	1.5	0.0026							0.15									715	905
U	0.05	0.14	0.41	0.009	0.0007	0.034	7.6	0.0151																567	720
V	0.06	0.15	0.85	0.002	0.0004	0.031	9.1	0.0026		0.50			0.15											543	670
Underlined values are outside the scope of the present invention.																									

[Table 2]

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE$_{196}$ (J)	Percentage Reduction of Area (%)	Class
1	A	30	Done	0.20	1100	6	3	Water Cooling	None	-	-	-	25	7	950	1150	76	70	Example
2	B	50	Done	0.20	1200	4	2	Air Cooling	Quenching-Tempering	685	-	526	30	5	720	790	210	80	Example
3	C	30	Done	0.20	1050	7	2	Water Cooling	Inter-critical Quenching-Tempering	-	611	524	15	9	705	760	205	80	Example
4	D	50	Done	0.20	1200	5	3	Water Cooling	Tempering	-	-	575	21	3	710	770	84	45	Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passeswith a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE-196 (J)	Percentage Reduction of Area (%)	Class
5	E	30	Done	0.20	1100	5	3	Air Cooling	Quenching- Inter-critical Quenching-Tempering	753	674	592	20	1	680	741	211	70	Example
6	F	30	Done	0.20	1250	6	2	Water Cooling	Inter-critical Quenching-Tempering	-	600	530	16	6	736	810	184	80	Example
7	G	50	Done	0.20	1050	3	3	Water Cooling	Tempering	-	-	637	24	2	721	774	201	60	Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE$_{196}$ (J)	Percentage Reduction of Area (%)	Class
8	H	50	Done	0.20	1100	4	2	Air Cooling	Quenching-Intercritical Quenching-Tempering	735	655	574	34	3	719	759	189	70	Example
9	I	30	Done	0.20	1150	5	3	Water Cooling	Quenching-Tempering	724	-	555	26	2	724	771	144	65	Example
10	J	30	Done	0.20	1100	6	3	Air Cooling	Quenching-Tempering	900	-	580	34	1	664	820	75	45	Example
11	K	50	Done	0.20	1200	6	2	Water Cooling	Tempering	-	-	594	20	3	654	709	175	70	Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE-$_{196}$ (J)	Percentage Reduction of Area (%)	Class
12	L	50	Done	0.20	1200	5	2	Water Cooling	Quenching-Intercritical Quenching-Tempering	687	617	549	19	2	741	780	106	45	Example
13	M	30	Done	0.20	1050	5	2	Air Cooling	Quenching-Tempering	712	-	540	23	2	721	767	81	40	Example
14	N	30	Done	0.20	1250	6	2	Air Cooling	Quenching-Tempering	762	-	589	24	3	716	771	71	40	Example
15	O	30	Done	0.20	1050	6	3	Water Cooling	Tempering	-	-	562	35	3	711	736	188	55	Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE-196 (J)	Percentage Reduction of Area (%)	Class
16	P	50	Done	0.20	1200	4	3	Air Cooling	Tempering	-	-	578	25	4	700	1120	25	15	Comparative Example
17	Q	30	Done	0.20	1200	6	2	Water Cooling	Tempering	-	-	605	26	14	771	902	54	20	Comparative Example
18	R	50	Done	0.20	1050	4	3	Water Cooling	Tempering	-	-	616	24	9	701	755	15	15	Comparative Example
19	S	30	Done	0.20	1150	5	3	Air Cooling	Quenching-Tempering	712	-	539	36	15	751	802	16	20	Comparative Example
20	S	50	not Done	-	1250	3	2	Water Cooling	Tempering	-	-	550	130	20	766	830	15	10	Comparative Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE-196 (J)	Percentage Reduction of Area (%)	Class
21	T	30	Done	0.20	1100	5	3	Air Cooling	Quenching-Tempering	850	-	640	24	5	400	560	6	70	Comparative Example
22	U	50	Done	0.20	1200	6	2	Water Cooling	Tempering	-	-	588	35	2	716	740	19	25	Comparative Example
23	D	30	Done	0.20	1050	6	0	Water Cooling	Tempering	-	-	580	150	4	716	765	54	15	Comparative Example
24	D	50	Done	0.20	1250	2	2	Water Cooling	Tempering	-	-	580	140	3	689	732	41	15	Comparative Example
25	L	50	Done	0.20	850	3	3	Water Cooling	Tempering	-	-	560	26	2	711	744	44	15	Comparative Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE-196 (J)	Percentage Reduction of Area (%)	Class
26	L	50	Done	0.20	1350	3	3	Water Cooling	Tempering	-	-	560	120	3	701	729	31	20	Comparative Example
27	A	50	not Done	-	1050	3	2	Water Cooling	Quenching-Tempering	750	-	570	30	12	750	780	79	30	Example
28	B	12	Done	0.20	1100	15	5	Air Cooling	Quenching- Inter-critical Quenching-Tempering	800	600	520	18	3	805	856	105	70	Example

(continued)

Sample No.	Material Code	Product Thickness (mm)	Soft Reduction	Reduction Gradient	Heating Temperature (°C)	Reduction Ratio	Number of Rolling Passes with a Rolling Shape Factor of 0.7 or More in Final 3 Rolling Passes	Treatment after Rolling	Heat Treatment	Quenching Temperature (°C)	Inter-critical Quenching Temperature (°C)	Tempering Temperature (°C)	Maximum Circle-Equivalent Diameter of Prior Austenite Grain (μm)	Number Density of MnS Particles Having a Major Axis of 100 μm or more (pieces/mm^2)	YS (MPa)	TS (MPa)	vE-$_{196}$ (J)	Percentage Reduction of Area (%)	Class
29	V	70	Done	0.20	1100	3	3	Air Cooling	Quenching-Intercritical Quenching-Tempering	780	670	580	30	6	620	705	206	50	Example
30	B	50	Done	0.20	1150	3	1	Water Cooling	Tempering	-	-	500	100	5	685	715	86	25	Comparative Example
31	A	40	Done	0.07	1100	4	2	Water Cooling	None	-	-	-	25	14	885	1085	69	30	Example
32	A	40	Done	0.10	1100	4	2	Water Cooling	None	-	-	-	24	14	878	1060	71	35	Example

Underlined values are outside the scope of the present invention.
*:Done in the final rolling pass

[0062] The examples of the present invention (sample Nos. 1 to 15, 27 to 29, 31, and 32) had a percentage reduction of area of 30% or more and excellent strength and low-temperature toughness. On the other hand, the comparative examples (sample Nos. 16 to 26 and 30), which were outside the scope of the present invention, were poor in terms of at least one of percentage reduction of area, strength, and low-temperature toughness.

Claims

1. A steel plate having a chemical composition containing,

   by mass%, C: 0.01% to 0.15%,
   Si: 0.01% to 1.00%,
   Mn: 0.10% to 2.00%,
   P: 0.010% or less,
   S: 0.0050% or less,
   Al: 0.002% to 0.100%,
   Ni: 5.0% to 10.0%,
   N: 0.0010% to 0.0080%, and with a balance being Fe and
   incidental impurities, and a percentage reduction of area of 30% or more in a tensile test in a thickness direction performed on a central portion in the thickness direction.

2. The steel plate according to Claim 1, wherein the chemical composition further contains, by mass%, one, two, or more selected from Cr: 0.01% to 1.50%,

   Mo: 0.03% to 1.0%,
   Nb: 0.001% to 0.030%,
   V: 0.01% to 0.10%,
   Ti: 0.003% to 0.050%,
   B: 0.0003% to 0.0100%, and
   Cu: 0.01% to 1.00%.

3. The steel plate according to Claim 1 or 2, wherein the chemical composition further contains, by mass%, one, two, or more selected from Sn: 0.01% to 0.30%,

   Sb: 0.01% to 0.30%,
   W: 0% (not inclusive) to 2.00%,
   Co: 0% (not inclusive) to 2.00%,
   Ca: 0.0005% to 0.0050%,
   Mg: 0.0005% to 0.0050%,
   Zr: 0.0005% to 0.0050%, and
   REM: 0.0010% to 0.0100%.

4. A method for manufacturing a steel plate, the method comprising heating a slab having the chemical composition according to any one of Claims 1 to 3 to a temperature of 1000°C or higher and 1300°C or lower and performing hot rolling on the heated slab in such a manner that finish rolling is performed with a reduction ratio of 3 or more and that each of at least two rolling passes of final three rolling passes is performed with a rolling shape factor of 0.7 or more.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/007377

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. C21D8/02(2006.01)i, C22C38/00(2006.01)i, C22C38/08(2006.01)i, C22C38/60(2006.01)i
FI: C22C38/00302B, C22C38/08, C22C38/60, C21D8/02D
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)
Int.Cl. C21D8/02, C22C38/00-C22C38/60

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	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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.
Y A	JP 11-28501 A (NIPPON STEEL CORPORATION) 02.02.1999 (1999-02-02), claims, paragraphs [0021]-[0033], [0035]-[0042], [0045], tables 1, 2	1-3 4
Y A	WO 2014/203347 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 24.12.2014 (2014-12-24), claims, paragraphs [0037], [0038], table 1	1-3 4
A	WO 2013/046357 A1 (NIPPON STEEL & SUMITOMO METAL CORPORATION) 04.04.2013 (2013-04-04), entire text, all drawings	1-4
A	CN 102586696 A (JIANGSU INSTITUTE OF RESEARCH OF IRON AND STEEL, SHA-STEEL CO., LTD.) 18.07.2012 (2012-07-18), entire text, all drawings	1-4

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13.05.2020	26.05.2020

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 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/JP2020/007377

JP 11-28501 A	02.02.1999	(Family: none)	
WO 2014/203347 A1	24.12.2014	EP 2871255 A1 claims, paragraphs [0023], [0024], table 1 JP 5561442 B1 KR 10-2015-0020258 A CN 104520461 A	
WO 2013/046357 A1	04.04.2013	US 2014/0158258 A1 entire text, all drawings JP 5059244 B1 EP 2743363 A1 CN 103764859 A KR 10-2014-0031408 A BR 112014003519 A2	
CN 102586696 A	18.07.2012	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007034576 A **[0004]**
- JP 2007080646 A **[0004]**
- JP 2011241419 A **[0004]**