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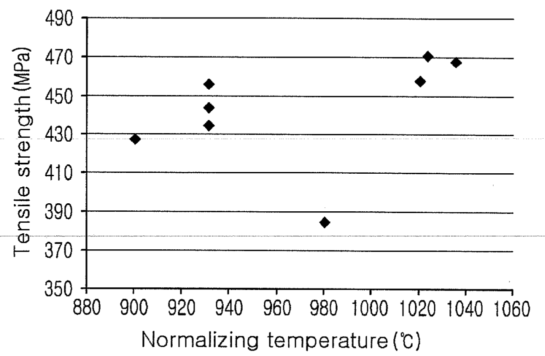
(54) **HEAVY-WALLED STEEL PLATE HAVING 450MPA-GRADE TENSILE STRENGTH AND EXCELLENT RESISTANCE TO HYDROGEN INDUCED CRACKING AND METHOD FOR MANUFACTURING SAME**

(57) The present disclosure relates to a heavy-wall steel plate having 450MPa-grade tensile strength and excellent resistance to hydrogen induced cracking, and a method for manufacturing the same. The heavy-wall steel plate includes, by weight, carbon (C): 0.03% to 0.06%, silicon (Si): 0.2% to 0.4%, manganese (Mn): 1.0% to 1.6%, phosphorus (P): 0.03% or less, sulfur (S): 0.003% or less, aluminum (Al): 0.06% or less, nitrogen (N): 0.01% or less, copper (Cu): 0.05% to 0.4%, nickel (Ni): 0.05% to 0.5%, calcium (Ca): 0.0005% to 0.003%, a balance of iron (Fe), and other unavoidable impurities, wherein a thickness of the heavy-wall steel plate is 40 mm or more.

【FIG. 1】



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Description

[Technical Field]

[0001] The present disclosure relates to a heavy-wall steel plate having excellent resistance to hydrogen induced cracking, and a method for manufacturing the same, and, in particular, to a normalizing heat treated heavy-wall steel plate having a thickness of 40 mm or more and having a tensile strength of 450 MPa, and a method for manufacturing the same.

[Background Art]

[0002] A heavy-wall steel plate for guaranteeing hydrogen induced cracking according to American Petroleum Institute (API) standard has been used for line pipe, process pipe, or the like, and the required properties and manufacturing process of a steel material has been used determined, depending on the usage environment. When the end customer has a high temperature environment, the manufacturing process of a steel material requires a heat treatment process such as a normalizing process, a quenching/tempering process, or the like. Furthermore, when manufacturing process of a steel pipe includes the normalizing process, a heat treatment steel plate requires a normalizing steel material.

[0003] However, the normalizing steel material is generally low in strength due to the characteristics of the air-cooling material, and when the content of the alloying elements such as C, Mn, and the like, increases in order to facilitate an increase in strength, the resistance to hydrogen induced cracking may decrease sharply. The reason is that the content of pearlite in the steel plate increases with the addition of C, Mn, and the like, and the resistance to hydrogen induced cracking decreases sharply over a certain percentage of the pearlite fraction. In addition, since the resistance to hydrogen induced cracking is reduced after the tubing of the steel pipe due to the characteristics of the normalized steel material, the requirements for resistance to hydrogen induced cracking have become stricter in recent years.

[0004] The following technologies have been proposed so far for the production of normalized steel material for securing the resistance to hydrogen induced cracking.

[0005] Korean Patent Publication No. 2004-0021117 proposes a steel material for a pressure vessel having a tensile strength of 600 MPa, which is excellent in toughness and used for materials such as boilers of a power plant, pressure vessels, or the like. The steel material for a pressure vessel proposed by the Patent Publication has a composition comprising, by weight, carbon (C): 0.08% to 0.16%, silicon (Si): 0.1% to 0.4%, manganese (Mn): 0.8% to 1.8%, molybdenum (Mo): 0.2% to 0.8%, nickel (Ni): 0.3% to 0.8%, boron (B): 0.0005% to 0.003%, titanium (Ti): 0.005% to 0.025%, aluminum (Al): 0.01% to 0.08%, phosphorus (P): 0.010% or less, sulfur (S): 0.010% or less, nitrogen (N): 0.010% or less, a balance of iron (Fe), and other unavoidable impurities. The steel material is heat-treated at a temperature in a range of Ac3 to 930°C, and, then, forcibly cooled to room temperature at a cooling rate of 0.5 to 5°C/sec. As described above, the Patent Publication relates to a steel material for a pressure vessel having a tensile strength of 600 MPa and a manufacturing method thereof.

[0006] However, the components and the manufacturing conditions described in the above-mentioned Korean Patent Publication No. 2004-0021117 have not been able to produce a normalizing steel material excellent in resistance to hydrogen induced cracking due to a high C content. Further, there is a disadvantage that Mo, not effective in improving the strength of the normalized steel, has been used intentionally_therein. In addition, despite the fact that Cu is not used, there is a disadvantage that a relatively large amount of Ni added is added to prevent hot shortness. Moreover, there is a problem that distribution of inclusions greatly affecting resistance to hydrogen induced cracking of a low-strength steel material is not considered.

[0007] Korean Patent No. 0833070 proposes a heavy-wall steel plate for a pressure vessel excellent in resistance to hydrogen induced cracking while satisfying a tensile strength of 500 MPa. In the heavy-wall steel plate for a pressure vessel proposed by the above Patent, and a method for manufacturing the same, a steel material having a composition comprising, by weight, carbon (C): 0.1% to 0.30%, silicon (Si): 0.15% to 0.40%, manganese (Mn): 0.6% to 1.2%, phosphorus (P): 0.035% or less, sulfur (S): 0.020% or less, aluminum (Al): 0.001% to 0.05%, chromium (Cr) : 0.35% or less, nickel (Ni): 0.5% or less, copper (Cu) : 0.5% or less, molybdenum (Mo) : 0.2% or less, vanadium (V) : 0.05% or less, niobium (Nb): 0.05% or less, calcium (Ca) : 0.0005% to 0.005%, a balance of iron (Fe), and other unavoidable impurities, is used. Further, such a steel plate satisfies Equation 1: Cu + Ni + Cr + Mo < 1.5%, Equation 2: Cr + Mo < 0.4%, Equation 3: V + Nb < 0.1%, and Equation 4: Ca/S > 1.0, as relationships for components. The above Patent relates to a method for manufacturing the steel material having a tensile strength of 500 MPa, as described above, comprising: reheating the steel material at 1050°C to 1250°C; performing a recrystallization controlled rolling operation of hot-rolling the reheated steel material at a temperature not lower than a non-recrystallization temperature; and performing a normalizing operation of heat treating the hot-rolled steel material at a temperature of 850°C to 950°C at 1.3 x t + (10 - 30 minutes) (where t denotes a thickness (mm) of a steel material).

[0008] However, since the above-mentioned Korean Patent No. 0833070, as in the Korean Patent Publication No.

2004-0021117, contains Cr, Mo, and V, which are less effective for improving the strength of the normalized steel, and, in addition, the C content described therein is 0.1 wt% or more, there is also a problem in securing the resistance to hydrogen induced cracking.

[Disclosure]

[Technical Problem]

[0009] The present disclosure is made to solve the above problems of the prior art, and it is an object of the present disclosure to optimize components in steel, a microstructure of the steel, a rolling operation, a cooling operation, and a heat treatment operation, to provide a normalizing heat treated heavy-wall steel plate having excellent resistance to hydrogen induced cracking, having a thickness of 40 mm or more and having a tensile strength of 450 MPa. In addition, unlike the prior art, the heat treatment operation is performed at a temperature higher than that of a conventional normalizing heat treatment operation without including expensive precipitation-type elements such as Cr, Mo, V, etc., to provide a normalizing heat treated heavy-wall steel plate having excellent resistance to hydrogen induced cracking, and having a tensile strength of 450 MPa.

[0010] The object of the present disclosure is not limited to the above description. Those skilled in the art will appreciate that there will be no difficulty in understanding the present disclosure from the overall contents of the present disclosure.

[Technical Solution]

[0011] According to an aspect of the present disclosure, a heavy-wall steel plate having excellent resistance to hydrogen induced cracking, includes, by weight, carbon (C): 0.03% to 0.06%, silicon (Si): 0.2% to 0.4%, manganese (Mn): 1.0% to 1.6%, phosphorus (P): 0.03% or less, sulfur (S): 0.003% or less, aluminum (Al): 0.06% or less, nitrogen (N): 0.01% or less, copper (Cu): 0.05% to 0.4%, nickel (Ni): 0.05% to 0.5%, calcium (Ca): 0.0005% to 0.003%, a balance of iron (Fe), and other unavoidable impurities, wherein a thickness of the heavy-wall steel plate is 40 mm or more, and tensile strength of the heavy-wall steel plate is 450 MPa or more.

[0012] The heavy-wall steel plate may further include niobium (Nb): 0.005% to 0.05% and titanium (Ti): 0.005% to 0.03%.

[0013] The heavy-wall steel plate may be a microstructure having a composite structure of ferrite and pearlite, and an area fraction of the pearlite may be less than 10%.

[0014] The heavy-wall steel plate may further include Al-Ca-based inclusions, and a minimum distance between Al-Ca-based inclusions having a diameter of 2 μm or more may be 100 μm or more in a rolling direction.

[0015] According to an aspect of the present disclosure, a method for manufacturing a heavy-wall steel plate having 450MPa-grade tensile strength and excellent resistance to hydrogen induced cracking, includes:

preparing a slab having a composition comprising, by weight, carbon (C): 0.03% to 0.06%, silicon (Si): 0.2% to 0.4%, manganese (Mn): 1.0% to 1.6%, phosphorus (P): 0.03% or less, sulfur (S): 0.003% or less, aluminum (Al): 0.06% or less, nitrogen (N): 0.01% or less, copper (Cu): 0.05% to 0.4%, nickel (Ni): 0.05% to 0.5%, calcium (Ca): 0.0005% to 0.003%, a balance of iron (Fe), and other unavoidable impurities;

heating the slab to 1100°C to 1300°C;

hot-rolling the heated slab such that the total rolling reduction thickness is less than 200 mm at a finish rolling temperature of 900°C or higher, so as to prepare a hot-rolled steel plate; and

subjecting the hot-rolled steel plate to a normalizing heat treatment at a temperature of 1000°C to 1100°C.

[Advantageous Effects]

[0016] According to an aspect of the present disclosure, by optimizing components in steel, a microstructure of the steel, and a rolling operation, a steel plate having excellent resistance to hydrogen induced cracking, having a thickness of 40 mm or more, and having a tensile strength of 450 MPa, at relatively low manufacturing costs.

[Description of Drawings]

[0017]

FIG. 1 is a graph illustrating distribution of tensile strengths according to normalizing temperatures of Comparative Examples 5 to 10, having the same components as those of Inventive Example 1.

FIG. 2 is a photograph showing Al-Ca-based inclusions in a hydrogen induced cracking fracture surface of Comparative Example 7 (low-temperature rolled material).

[Best Mode for Invention]

[0018] may help toughness and strength improvement. However, when the content thereof exceeds 0.01%, N is present in a solid-soluble state and N in a solid-soluble state has an adverse influence on low temperature toughness. Therefore, it is preferable to limit the content thereof to 0.01% or less.

Cu: 0.05% to 0.4%

[0019] Cu may be an element for improving the strength of ferrite through solid solution strengthening, and should be added in an amount of 0.05% or more. Since Cu is an element which causes cracks on the surface during a hot-rolling operation to hinder the surface quality, it is preferable to restrict the upper limit thereof to 0.4%.

Ni: 0.05% to 0.5%

[0020] Ni may be an element which improves the toughness of steel, and is preferably added in an amount of 0.05% or more, to reduce surface cracks generated during a hot-rolling operation of Cu-added steel. In addition, the Ni content of 0.5% or more may increase price of the steel material. Therefore, it is preferable to restrict the upper limit thereof to 0.5%.

Ca: 0.0005% to 0.003%

[0021] Ca may serve to spheroidize MnS inclusions. MnS, an inclusion having a relatively low melting point, produced in the central portion, may be stretched upon rolling to be present as a stretched inclusion in the central portion of steel. When MnS is present in a relatively large amount and partially dense, it may serve to decrease elongation when stretched in a thickness direction. The added Ca may react with MnS to surround MnS, thereby interfering with the stretching of MnS. In order to represent this MnS spheroidizing effect, Ca should be added in an amount 0.0005 wt % or more. Since Ca has high volatility and thus, has a relatively low yield, considering the load produced in the steel manufacturing process, it is preferable to restrict the upper limit thereof to 0.003 wt % or less.

[0022] The steel plate of the present disclosure may further include Nb and Ti optionally in addition to the above-mentioned composition.

Nb: 0.005 to 0.05%

[0023] Nb may be solid-solubilized when reheating a slab, and may inhibit austenite crystal grain growth during a hot rolling operation, and, then, may be precipitated to improve the strength of steel to 0.005% or more. When Nb is added in an excess amount exceeding 0.05%, it is precipitated together with Ti in the central portion to induce hydrogen induced cracking, such that the upper limit of Nb is limited to 0.05% in the present disclosure.

Ti: 0.005 to 0.03%

[0024] Ti may be an element effective in inhibiting the growth of austenite crystal grains by being bonded to N when reheating the slab to form TiN. When Ti is added in an amount exceeding 0.03%, the low-temperature impact toughness of the heat-treated material may deteriorate. Therefore, the upper limit of Ti is limited to 0.03% in the present disclosure. From the viewpoint of low-temperature toughness, it is more preferable to add 0.01% or less.

[0025] The steel plate of the present disclosure may further include Fe and unavoidable impurities, and does not exclude the addition of other components in addition to the above-described components. For example, the steel plate of the present disclosure may additionally include other components in addition to the above-mentioned components in the composition of steel.

[0026] The steel having the above composition may have different microstructures depending on the contents of the elements, rolling operations, cooling conditions, and heat treatment conditions, and may affect strength and resistance to hydrogen induced cracking depending on the microstructure even with the same composition. Hereinafter, a microstructure of a normalized steel material of the present disclosure, having excellent resistance to hydrogen induced cracking, having a thickness of 40 mm or more, and having a tensile strength of 450 MPa, will be described.

Matrix Structure: Complex Structure of Ferrite and Pearlite

[0027] The steel plate having excellent resistance to hydrogen induced cracking according to the present disclosure may be a steel plate having a thickness of 40 mm or more, and may be a steel plate having excellent in resistance to hydrogen induced cracking while maintaining a relatively high strength of 450 MPa or more in tensile strength, regardless of its thickness. In general, a normalized steel has two phases of ferrite and pearlite as its matrix structure without adding excessive components. When a pearlite fraction in the matrix structure is 10% or more, since resistance to hydrogen induced cracking is lowered, the pearlite fraction in the present disclosure may be limited to less than 10%.

Minimum Distance between Al-Ca-based Inclusions having Diameter of 2 μm or more: 100 μm or more

[0028] The Al-Ca-based inclusions may be a factor deteriorating the resistance to hydrogen induced cracking of low strength steel. When the minimum distance between Al-Ca-based inclusions having a diameter of 2 μm or more in a rolling direction is less than 100 μm, the resistance to hydrogen induced cracking may be deteriorated. It is preferable that a lower limit in the minimum distance between the Al-Ca-based inclusions having a diameter of 2 μm or more be limited to 100 μm.

[0029] Next, a method of manufacturing a normalized heat-treated steel plate of the present disclosure, having excellent resistance to hydrogen induced cracking, having a thickness of 40 mm or more, and having a tensile strength of 450 MPa, will be described.

[0030] First, in the present disclosure, a steel slab having the above-mentioned composition may be prepared, and, then, may be reheated in a temperature range of 1100°C to 1300°C.

[0031] The reheating process is an operation of heating the steel slab to a relatively high temperature, to hot-roll the steel slab. When the reheating temperature is higher than the upper limit of 1300°C defined by the present disclosure, the austenite crystal grains may be excessively coarsened to lower the strength of steel, and to generate scale defects. When the reheating temperature is less than 1100°C, re-solid soluble ratio of the alloying elements may decrease. Accordingly, in the present disclosure, the range of the reheating temperature is preferably limited to 1100°C to 1300°C, and more preferably 1100°C to 1180°C in terms of strength and toughness.

[0032] In the present disclosure, the heated slab may be hot-rolled such that the total rolling reduction thickness is less than 200 mm at a finish rolling temperature of 900°C or higher, so as to prepare a hot-rolled steel plate.

[0033] The lower the finish rolling temperature is, the finer the crystal grains are. Therefore, the low-temperature toughness of the steel may be improved. However, when the finish rolling temperature is lower than 900°C, large Al-Ca-based inclusions may be divided in the rolling direction, such that a minimum distance between Al-Ca-based inclusions having a diameter of 2 μm or more is less than 100 μm. Therefore, since the resistance to hydrogen induced cracking in the steel may be rapidly deteriorated, it is preferable to hot-roll the heated slab that the total rolling reduction thickness in the present disclosure is limited to be less than 200 mm.

[0034] In the case of a Thermo-Mechanical Controlling Process (TMCP) material, as the total rolling reduction thickness of the slab increases, the crystal grains may be finer and the low-temperature toughness may be improved. When the total rolling reduction thickness of the slab is 200 mm or more, the Al-Ca-based inclusions of a normalizing steel material may be easily divided in the rolling direction during a rolling operation, such that a minimum distance between Al-Ca-based inclusions having a diameter of 2 μm or more is less than 100 μm. Therefore, since the resistance to hydrogen induced cracking in the steel may be rapidly deteriorated, it is preferable to hot-roll the heated slab that the total rolling reduction thickness in the present disclosure is limited to be 200 mm or less.

[0035] In the present disclosure, the hot-rolled steel plate may be cooled, preferably by air cooling. Since the steel material to be provided is subjected to a heat treatment after rolling, the cooling process is not an important process variable, but when the steel plate is water cooled from a relatively high temperature, it may cause shape deformation and productivity resistance of the steel plate.

[0036] In the present disclosure, the hot-rolled steel plate is subjected to a normalizing treatment in a temperature range of 1000°C to 1100°C.

[0037] The normalizing temperature refers to a temperature at which the cooled steel plate is reheated to the austenite region at a certain temperature or more after the hot-rolling operation, and an air cooling operation may perform after the heating operation. In general, the normalizing temperature may be performed directly on the Ar3 temperature. Since the normalizing temperature range proposed in this study is aimed at coarsening crystal grain through the austenite crystal grain growth, it may deviate from the normal normalizing temperature.

[0038] In the present disclosure, when the normalizing temperature is less than 1000°C, the austenite crystal grains may be not sufficiently coarsened. Therefore, no sufficient quenchability may be secured at the time of the air cooling operation, and ferrite and pearlite formed at the time of the air cooling operation may not be completely transformed into austenite phase. When the normalizing temperature exceeds 1100°C, the austenite crystal grains may be excessively coarsened. Therefore, the low-temperature toughness may deteriorate and a high-temperature scale may be caused on the surface of the steel. In consideration of this, in the present disclosure, the range of the normalizing reheating temperature is preferably limited to 1000°C to 1100°C.

[Mode for Invention]

[0039] Hereinafter, the present disclosure will be described more specifically by way of examples. It should be noted, however, that the following examples are intended to illustrate and specify the present disclosure, and not to limit the scope of the present disclosure. This is because the scope of the present disclosure is determined by the matters described in the claims and the matters reasonably deduced therefrom.

(Example)

[0040] Steel slabs having the composition illustrated in the following Table 1 were reheated, hot-rolled, and normalized to produce steel plates. In the following Tables 2 and 3, inventive examples comply with the steel composition and the manufacturing conditions according to an aspect of the present disclosure, and comparative examples deviate from any one of the steel composition and the manufacturing conditions according to an aspect of the present disclosure.

[0041] The steel types illustrated in the following Table 1 were prepared to produce steel plates according to the manufacturing process conditions illustrated in the following Table 2. Specifically, the steel slab having the composition illustrated in the following Table 1 was heated to the heating temperature illustrated in the following Table 2, rolled to the finish rolling temperature and the total rolling reduction thickness illustrated in the following Table 2, reheated to the reheating temperature illustrated in the following Table 2, and then air-cooled.

[0042] A pearlite area fraction, a distance between the Al-Ca-based inclusions, tensile strength, and a hydrogen induced cracking sensitivity, e.g., a crack length ratio (CLR) were measured for the thus prepared steel plate, and the results are illustrated in the following Table 3.

[0043] The pearlite area fraction and the distance between the Al-Ca-based inclusions were obtained by observing the microstructure of the steel plate, and the hydrogen induced cracking sensitivity (CLR) was tested according to the method specified by a National Association of Corrosion Engineers (NACE), and percentage of the length of the hydrogen induced cracking generated with respect to the entire length of the specimen.

[0044] The values listed in the following Table 1 refer to weight percent. Comparative Examples 1 to 4 are comparative examples in which the components having steel composition and the manufacturing process conditions fail to satisfy the ranges according to an aspect of the present disclosure, and Comparative Examples 5 to 10 are comparative examples in which the components having steel composition satisfy the ranges according to an aspect of the present disclosure, but the manufacturing process conditions fail to satisfy the ranges according to an aspect of the present disclosure.

[Table 1]

Steel	C	Si	Mn	P	S	Al	N	Cr	Mo	Cu	Ni	Mb	Ti	V	Ca
1	0.041	0.31	1.32	0.007	0.0008	0.03	0.005			0.31	0.24	0.02	0.01		0.0015
2	0.038	0.32	1.34	0.008	0.0007	0.029	0.004			0.29	0.22		0.01		0.0013
3	0.068	0.25	1.51	0.008	0.0008	0.041	0.005	0.19	0.14	0.2	0.23	0.006	0.008	0.02	0.001
4	0.043	0.22	1.2	0.008	0.0008	0.041	0.005	0.27	0.12			0.014	0.013	0.012	0.0013
5	0.048	0.25	1.75	0.008	0.0009	0.033	0.005	0.18	0.09	0.08		0.013	0.01		0.0014
6	0.043	0.12	1.35	0.008	0.0008	0.029	0.007			0.18	0.25	0.012	0.03		0.0011
* The remainder in Table 1 is Fe and unavoidable impurities.															

[Table 2]

Example		Heat Temp. (°C)	Finish Rolling Temp. (°C)	Total Rolling Reduction Thickness(mm)	Normalizing Temp. (°C)
Inventive Example	1	1168	977	188	1035
	2	1159	966	176	1023
Comparative Example	1	1165	990	192	915
	2	1152	975	188	942
	3	1145	935	179	928
	4	1144	964	167	925
	5	1133	891	193	931
	6	1121	876	196	931
	7	1137	835	184	931
	8	1122	955	179	980
	9	1160	952	185	900
	10	1160	973	240	1020

[Table 3]

Steel	Example	Pearlite Area Fraction (%)	Al-Ca-based Inclusion Minimum Distance (μm)	Tensile Strength (MPa)	Hydrogen Induced Cracking Sensitivity (CLR, %)
1	*IE1	5.2	332	468	0
2	IE2	5.1	430	471	0.1
3	**CE1	12.5	266	457	4.8
4	CE2	3.6	343	387	0
5	CE3	5.8	136	466	12.6
6	CE4	6.1	144	384	0
1	CE5	5.2	86	435	3.5
	CE6	5.3	63	444	10.7
	CE7	5.1	35	456	32.5
	CE8	5	361	385	0
	CE9	5.3	345	428	0
	CE10	5.8	92	461	1.2
*IE: Inventive Example, **CE: Comparative Example					

[0045] Referring to Tables 1 to 3 above, Inventive Examples 1 and 2 satisfying the steel composition and the manufacturing process conditions according to an aspect of the present disclosure, have a tensile strength of 450 MPa or more and a hydrogen induced cracking sensitivity (CLR) of 1% or less, and, thus, it can be seen that resistance to hydrogen induced cracking thereon is excellent.

[0046] Comparative Examples 1 to 10, which fail to satisfy one of the component system, component range, and process conditions according to an aspect of the present disclosure, have a tensile strength of less than 450 MPa, or a hydrogen induced cracking sensitivity (CLR) exceeding 1%, and, thus, it can be seen that resistance to hydrogen induced cracking thereon was not sufficient.

[0047] As reported above, it can be seen that a steel plate having excellent resistance to hydrogen induced cracking, having a thickness of 40 mm or more, and having a tensile strength of 450 MPa, may be obtained by manufacturing the steel plate according to the composition and manufacturing process of the present disclosure.

[0048] While exemplary embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present disclosure as defined by the appended claims.

Claims

1. A heavy-wall steel plate having excellent resistance to hydrogen induced cracking, comprising, by weight, carbon (C) : 0.03% to 0.06%, silicon (Si) : 0.2% to 0.4%, manganese (Mn) : 1.0% to 1.6%, phosphorus (P): 0.03% or less, sulfur (S): 0.003% or less, aluminum (Al): 0.06% or less, nitrogen (N): 0.01% or less, copper (Cu): 0.05% to 0.4%, nickel (Ni): 0.05% to 0.5%, calcium (Ca): 0.0005% to 0.003%, a balance of iron (Fe), and other unavoidable impurities,
wherein a thickness of the heavy-wall steel plate is 40 mm or more, and
tensile strength of the heavy-wall steel plate is 450 MPa or more.

2. The heavy-wall steel plate according to claim 1, further comprising niobium (Nb): 0.005% to 0.05% and titanium (Ti): 0.005% to 0.03%.

3. The heavy-wall steel plate according to claim 1, wherein the heavy-wall steel plate is a microstructure having a composite structure of ferrite and pearlite, and an area fraction of the pearlite is less than 10%.

4. The heavy-wall steel plate according to claim 1, wherein the heavy-wall steel plate further comprises Al-Ca-based inclusions, and a minimum distance between Al-Ca-based inclusions having a diameter of 2 μm or more is 100 μm or more in a rolling direction.

5. The heavy-wall steel plate according to claim 1, wherein a hydrogen induced cracking sensitivity of the heavy-wall steel plate has a crack length ratio (CLR) of 1% or less.

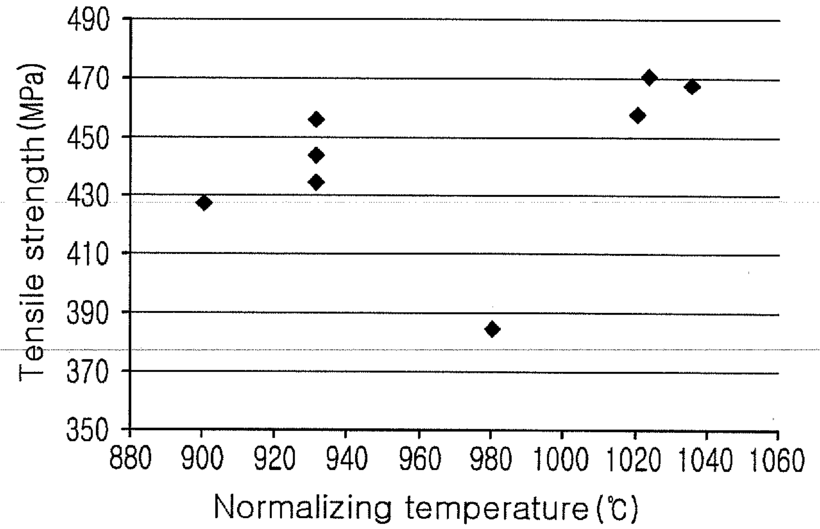
6. A method for manufacturing a heavy-wall steel plate having 450MPa-grade tensile strength and excellent resistance to hydrogen induced cracking, comprising:

   preparing a slab having a composition comprising, by weight, carbon (C): 0.03% to 0.06%, silicon (Si): 0.2% to 0.4%, manganese (Mn): 1.0% to 1.6%, phosphorus (P): 0.03% or less, sulfur (S): 0.003% or less, aluminum (Al): 0.06% or less, nitrogen (N): 0.01% or less, copper (Cu): 0.05% to 0.4%, nickel (Ni): 0.05% to 0.5%, calcium (Ca) : 0.0005% to 0.003%, a balance of iron (Fe), and other unavoidable impurities;
   heating the slab to 1100°C to 1300°C;
   hot-rolling the heated slab such that the total rolling reduction thickness is less than 200 mm at a finish rolling temperature of 900°C or higher, so as to prepare a hot-rolled steel plate; and
   subjecting the hot-rolled steel plate to a normalizing heat treatment at a temperature of 1000°C to 1100°C.

7. The method according to claim 6, wherein the heavy-wall steel plate is a microstructure having a composite structure of ferrite and pearlite, and an area fraction of the pearlite is less than 10%.

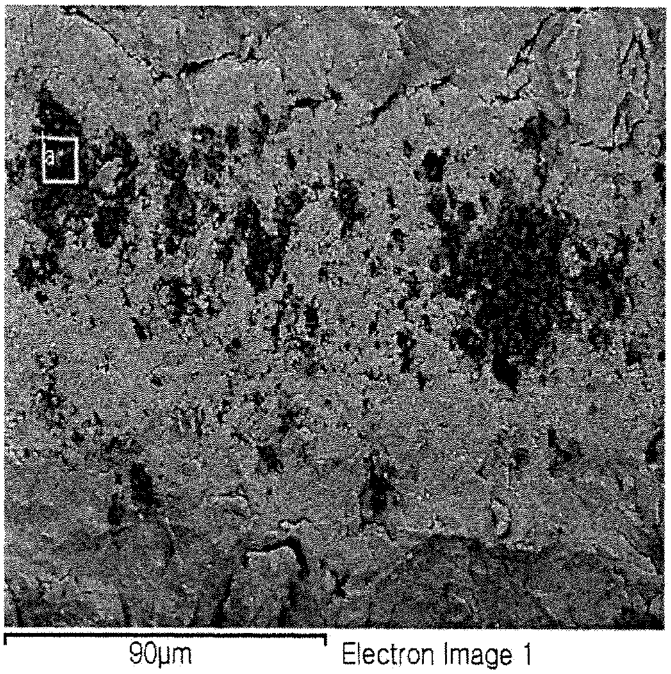
8. The method according to claim 6, wherein the heavy-wall steel plate further comprises Al-Ca-based inclusions, and a minimum distance between Al-Ca-based inclusions having a diameter of 2 μm or more is 100 μm or more in a rolling direction.

【FIG. 1】



Tensile strength (MPa)
490
470
450
430
410
390
370
350
880
900
920
940
960
980
1000
1020
1040
1060
Normalizing temperature (℃)

【FIG. 2】


a
90μm
Electron Image 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2017/013550

A. CLASSIFICATION OF SUBJECT MATTER
C22C 38/04(2006.01)i, C22C 38/02(2006.01)i, C22C 38/06(2006.01)i, C22C 38/00(2006.01)i, C22C 38/16(2006.01)i, C22C 38/08(2006.01)i, C21D 8/02(2006.01)i, C21D 1/28(2006.01)i
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)
C22C 38/04; C21D 8/02; C22C 38/00; C22C 38/60; C22C 38/14; C22C 38/02; C22C 38/06; C22C 38/16; C22C 38/08; C21D 1/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models: IPC as above
Japanese Utility models and applications for Utility models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS (KIPO internal) & Keywords: hydrogen induced cracking, normalizing, rear plate, thickness, Cu, Ni, Ca, Nb, Ti

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	KR 10-0622888 B1 (JFE STEEL CORPORATION) 14 September 2006 See paragraphs [0010], [0085], [0092]-[0094] and claims 1-3.	1-3 4-8
X	KR 10-2011-0060449 A (POSCO) 08 June 2011 See paragraphs [0064]-[0067], [0079] and claims 1, 3, 6.	1-3
A	JP 2014-218707 A (JFE STEEL CORP.) 20 November 2014 See paragraphs [0064], [0065] and claims 1-4.	1-8
A	KR 10-2014-0002256 A (HYUNDAI STEEL COMPANY) 08 January 2014 See paragraph [0072] and claims 1, 5.	1-8
A	JP 2003-226933 A (SUMITOMO METAL IND. LTD.) 15 August 2003 See paragraph [0062] and claim 1.	1-8

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
06 APRIL 2018 (06.04.2018)	**06 APRIL 2018 (06.04.2018)**

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Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2017/013550

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- KR 0833070 **[0007] [0008]**