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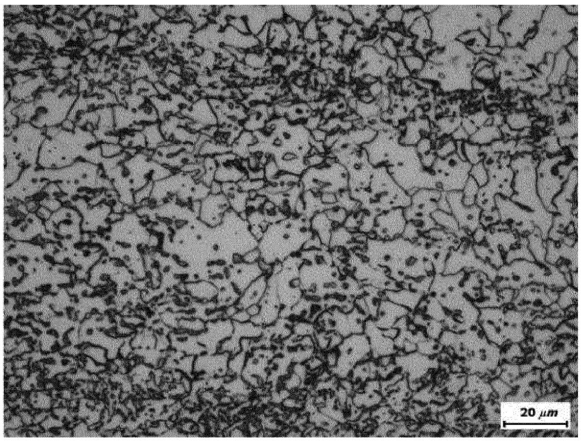
(54) HIGH STRENGTH STEEL PLATE HAVING EXCELLENT LOW YIELD RATIO CHARACTERISTICS AND LOW TEMPERATURE TOUGHNESS AND METHOD FOR MANUFACTURING SAME

(57) One aspect of the present invention relates to a high strength steel plate having excellent low yield ratio characteristics and low temperature toughness, comprising, by weight %: C: 0.03 to 0.08%; Si: 0.05 to 0.3%; Mn: 1.0 to 2.0%; Al: 0.005 to 0.04%; Nb: 0.005 to 0.04%; Ti: 0.001 to 0.02%; Cu: 0.05 to 0.4%; Ni: 0.6 to 2.0%; Mo: 0.08 to 0.3%; N: 0.002 to 0.006%; P: 0.01% or less; S: 0.003% or less; and the remainder being Fe and unavoidable impurities, in which a microstructure contains, by area fraction, 80 to 92% of ferrite, 8 to 20% of a martensite/austenite mixed structure (MA), wherein the MA has an average size measured as a circle-equivalent diameter of 3 μm or less.

【Figure 1】



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Description

[Technical Field]

[0001] The present disclosure relates to a high strength steel plate having low yield ratio characteristics and low temperature toughness, and a method for manufacturing the high strength steel plate.

[Background Art]

[0002] In addition to steel materials for shipbuilding and marine structures, the development of steel materials having a low yield ratio, in addition to having ultra-low temperature toughness, is required for applications in industrial fields requiring formability and seismic resistance.

[0003] Since steel materials having a low yield ratio have a great difference between yield strength and tensile strength, the steel materials have high formability, and the start of plastic deformation of the steel materials may be delayed until fracture may occur, such that collapses caused by external force may be prevented, owing to absorption of energy during the delay. In addition, even if a structure is deformed, the structure may be repaired before collapse so as to prevent damage to property and human life caused by breakage of the structure.

[0004] Techniques for manufacturing steel materials having a two-phase microstructure have been developed to guarantee a low yield ratio. Specifically, a low yield ratio has been realized by forming soft ferrite as a first phase, and martensite, pearlite, or bainite as a second phase.

[0005] However, the second phase which is relatively hard decreases impact toughness, and since the content of carbon is increased to form the second phase, the toughness of a weld zone deteriorates. Therefore, brittle fraction may occur in a structure at a low temperature.

[0006] Thus, a technique for guaranteeing a low yield ratio and low temperature toughness has been disclosed in Patent Document 1.

[0007] In Patent Document 1, a low yield ratio and high low-temperature toughness are guaranteed by a microstructure including MA (a mixed structure of martensite/austenite) in an amount of 2 vol% to 10 vol% and acicular ferrite in an amount of 90 vol% or greater.

[0008] In Patent Document 1, a yield ratio of about 0.8 may be guaranteed, but this is not sufficient to ensure seismic resistance.

[0009] Therefore, for a lower yield ratio, there is a need for the development of a high strength steel plate having low yield ratio characteristics and low temperature toughness, and a method for manufacturing the high strength plate.

(Related Art Documents)

[0010] (Patent Document 1) Korean Patent Application Laid-open Publication No. 2013-0076577

[Disclosure]

[Technical Problem]

[0011] An aspect of the present disclosure may provide a high strength steel plate having low yield ratio characteristics and low temperature toughness, and a method for manufacturing the high strength steel plate.

[0012] Aspects of the present disclosure are not limited to the above-mentioned aspects. The above-mentioned aspects and other aspects of the present disclosure will be clearly understood by those skilled in the art through the following description.

[Technical Solution]

[0013] According to an aspect of the present disclosure, a high strength steel plate having low yield ratio characteristics and low temperature toughness may include, by wt%, C: 0.03% to 0.08%, Si: 0.05% to 0.3%, Mn: 1.0% to 2.0%, Al: 0.005% to 0.04%, Nb: 0.005% to 0.04%, Ti: 0.001% to 0.02%, Cu: 0.05% to 0.4%, Ni: 0.6% to 2.0%, Mo: 0.08% to 0.3%, N: 0.002% to 0.006%, P: 0.01% or less, S: 0.003% or less, and a balance of Fe and inevitable impurities,
wherein a microstructure of the high strength steel plate may include, by area%, ferrite in an amount of 80% to 92% and MA (a mixed structure of martensite/austenite) in an amount of 8% to 20%, and the MA has an average size of 3 μm or less when measured in equivalent circular diameter.

[0014] According to another aspect of the present disclosure, a method for manufacturing a high strength steel plate having low yield ratio characteristics and low temperature toughness may include:

heating a slab to a temperature of 1050°C to 1200°C, the slab having, by wt%, C: 0.03% to 0.08%, Si: 0.05% to 0.3%, Mn: 1.0% to 2.0%, Al: 0.005% to 0.04%, Nb: 0.005% to 0.04%, Ti: 0.001% to 0.02%, Cu: 0.05% to 0.4%, Ni: 0.6% to 2.0%, Mo: 0.08% to 0.3%, N: 0.002% to 0.006%, P: 0.01% or less, S: 0.003% or less, and a balance of Fe and inevitable impurities;
hot rolling the heated slab in such a manner that a finish rolling termination temperature ranges from 760°C to 850°C, so as to obtain a hot-rolled steel plate;
cooling the hot-rolled steel plate to a temperature of 450°C or less at a cooling rate of 5°C/s or greater; and
after heating the cooled hot-rolled steel plate to a temperature of 850°C to 960°C, maintaining the hot-rolled steel plate for [1.3t+(10~30)] minutes,
(where t is a thickness of the hot-rolled steel plate in millimeters (mm)).

[0015] The above-described aspects of the present disclosure do not include all aspects or features of the present disclosure. Other aspects or features, and effects of the present disclosure will be clearly understood from the following descriptions of exemplary embodiments.

[Advantageous Effects]

[0016] The high strength steel plate of the present disclosure may have low yield ratio characteristics and low temperature toughness. Specifically, the high strength steel plate may have a low yield ratio within the range of 0.65 or less, high formability, and high seismic resistance.

[0017] Therefore, the high strength steel plate may be applied not only to shipbuilding and marine structures but also to industrial fields requiring formability and seismic resistance.

[Description of Drawings]

[0018]

FIG. 1 is an image of the microstructure of test no. 1 (inventive example) captured using an optical microscope (OM) .
FIG. 2 is an image of the microstructure of test no. 1 (inventive example) captured using a scanning electron microscope (SEM).
FIG. 3 is an image of the microstructure of test no. 12 (comparative example) captured using an OM.

[Best Mode]

[0019] Embodiments of the present disclosure will now be described in detail. The disclosure may, however, be exemplified in many different forms and should not be construed as being limited to the specific embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present disclosure to those skilled in the art.

[0020] The inventors have recognized that although formability is somewhat ensured by a yield ratio of about 0.8 in the related art, the yield ratio level obtainable in the related art is not sufficiently low to guarantee seismic resistance. Thus, the inventors have conducted deep research to address this problem.

[0021] As a result, the inventors have found the followings: as the hardness difference between a base material and a second phase increases, a low yield ratio is realized; a uniform distribution of MA (a mixed structure of martensite/austenite) is favored; and in the case of Patent Document 1, the hardness difference between a base material, that is, acicular ferrite, and MA is insufficient, and the MA is formed along grain boundaries and is coarse, thereby failing to obtain a sufficiently low yield ratio.

[0022] The inventors have found that a yield ratio of 0.65 or less can be obtained by forming ferrite as the microstructure of a base material and uniformly distributing a fine MA phase along ferrite grain boundaries and in ferrite grains, and this structure can be obtained by adjusting a microstructure to have bainite before a normalizing heat treatment. Then, based on this knowledge, the inventors have invented the present invention.

[0023] Hereinafter, a high strength steel plate having low yield ratio characteristics and low temperature toughness will be described in detail according to an aspect of the present disclosure.

[0024] According to the aspect of the present disclosure, the high strength steel plate having low yield ratio characteristics and low temperature toughness includes, by wt%, C: 0.03% to 0.08%, Si: 0.05% to 0.3%, Mn: 1.0% to 2.0%, Al: 0.005% to 0.04%, Nb: 0.005% to 0.04%, Ti: 0.001% to 0.02%, Cu: 0.05% to 0.4%, Ni: 0.6% to 2.0%, Mo: 0.08% to 0.3%, N: 0.002% to 0.006%, P: 0.01% or less, S: 0.003% or less, and the balance of Fe and inevitable impurities,
wherein the microstructure of the high strength steel plate includes, by area%, ferrite in an amount of 80% to 92% and MA (a mixed structure of martensite/austenite) in an amount of 8% to 20%, and the MA has an average size of 3 μm or

less measured in equivalent circular diameter.

[0025] First, the alloy composition of the high strength steel plate having low yield ratio characteristics and low temperature toughness will be described in detail according to the aspect of the present disclosure. In the following description, the content of each element is given in wt%.

Carbon (C): 0.03% to 0.08%

[0026] In the present disclosure, C is an element leading to solid solution strengthening and being present as a carbonitride of Nb or the like, and thus C guarantees tensile strength.

[0027] When the content of C is less than 0.03%, the above-mentioned effects are insufficient. However, when the content of C is greater than 0.08%, MA is coarsened, and pearlite is formed, thereby deteriorating impact characteristics at low temperatures and making it difficult to sufficiently form bainite.

Silicon (Si): 0.05% to 0.3%

[0028] Si is added to assist Al in deoxidizing molten steel and guaranteeing yield strength and tensile strength.

[0029] When the content of Si is less than 0.05%, the above-mentioned effects are insufficient. However, when the content of Si is greater than 0.3%, due to coarsening of MA, impact properties may deteriorate, and welding characteristics may deteriorate.

Manganese (Mn): 1.0% to 2.0%

[0030] Mn is an element that contributes greatly to the strength enhancement effect by solid solution strengthening and helps the formation of bainite.

[0031] When the content of Mn is less than 1.0%, the above-mentioned effects are insufficient. However, excessively added Mn may cause inclusion of MnS and degradation of toughness due to central segregation, and thus the upper limit of the content of Mn is set to be 2.0%.

Aluminum (Al): 0.005% to 0.04%

[0032] Al is a major deoxidizer of steel and may be added in an amount of 0.005% or greater. However, if the content of Al is greater than 0.04%, this effect is saturated, and the fraction and size of Al_2O_3 inclusions increase to cause a decrease in low temperature toughness.

Niobium (Nb): 0.005% to 0.04%

[0033] Nb is an element staying in a solid solution state or precipitating carbonitrides during rolling or cooling, thereby suppressing recrystallization, promoting the formation of a fine microstructure, and increasing strength. When the content of Nb is less than 0.005%, the above-mentioned effects are insufficient. However, when the content of Nb exceeds 0.04%, the toughness of a base material and the toughness of the steel plate after welding may be lowered.

Titanium (Ti): 0.001% to 0.02%

[0034] Ti forms precipitates by combining with oxygen or nitrogen, thereby suppressing coarsening of a microstructure, contributing to refinement, and improving toughness.

[0035] When the content of Ti is less than 0.001%, the above-mentioned effects are insufficient. However, when the content of Ti exceeds 0.02%, coarse precipitates may be formed to cause fracture.

Copper (Cu): 0.05% to 0.4%

[0036] Cu is an element that does not markedly deteriorate impact characteristics and improves strength by solid solution strengthening and precipitation strengthening. For sufficient strength improvements, Cu is required to be added in an amount of 0.05% or greater. However, if the content of Cu exceeds 0.4%, surface cracks may be formed in the steel plate due to Cu thermal shock.

Nickel (Ni): 0.6% to 2.0%

[0037] Although significant strength improvements are not obtained by increasing the content of Ni, Ni improves strength and toughness at the same time and promotes the formation of bainite by lowering the Ar3 temperature.

[0038] When the content of Ni is less than 0.6%, the above-mentioned effects are insufficient. However, when the content of Ni exceeds 2.0%, manufacturing costs may increase and weldability may deteriorate.

Molybdenum (Mo): 0.08% to 0.3%

[0039] Mo, serving as an austenite stabilizing element, has an effect on increasing the amount of MA and plays a large role in improving strength. In addition, Mo prevents a decrease in strength during a heat treatment process and promotes the formation of bainite.

[0040] When the content of Mo is less than 0.08%, the above-mentioned effects are insufficient. However, when the content of Mo exceeds 0.3%, manufacturing costs may increase, and the toughness of a base material and the toughness of the supply pipe after welding may decrease.

Nitrogen (N): 0.002% to 0.006%

[0041] N is an element useful in improving strength and toughness because N forms precipitates together with elements such as Ti, Nb, or Al and thus leads to the formation of fine austenite when a slab is heated.

[0042] When the content of N is less than 0.002%, the above-mentioned effects are insufficient. However, when the content of N is greater than 0.006%, surface cracks may be formed at a high temperature, and N remaining in an atomic state after precipitation reduces toughness.

Phosphorus (P): 0.01% or less

[0043] P, as an impurity, may cause grain boundary segregation and may thus cause embrittlement of steel. Therefore, the upper limit of the content of P is adjusted. Preferably, the upper limit of the content of P is adjusted to be 0.01% or less.

Sulfur (S): 0.003% or less

[0044] S is an impurity mainly combining with Mn to form MnS inclusions which are factors decreasing low temperature toughness. Therefore, the upper limit of the content of S is adjusted. Preferably, the upper limit of the content of S is adjusted to be 0.003% or less.

[0045] The other component of the steel plate of the present disclosure is iron (Fe). However, impurities of raw materials or manufacturing environments may be inevitably included in the steel plate, and such impurities may not be removed from the steel plate. Such impurities are well-known to those of ordinary skill in manufacturing industries, and thus specific descriptions of the impurities will not be given in the present disclosure.

[0046] Hereinafter, the microstructure of the high strength steel plate having low yield ratio characteristics and low temperature toughness will be described in detail according to an aspect of the present disclosure.

[0047] According to the aspect of the present disclosure, the microstructure of the high strength steel plate having low yield ratio characteristics and low temperature toughness includes: by area%, ferrite in an amount of 80% to 92% and MA in an amount of 8% to 20%, and the MA has an average size of 3 μm or less measured in equivalent circular diameter. In the following description, the fraction of a microstructure refers to an area fraction (area%) unless otherwise specified.

[0048] Ferrite basically guarantees toughness and strength, and it is preferable that the fraction of ferrite be 80% or greater. In addition, it is preferable that the upper limit of the fraction of ferrite be 92% for guaranteeing the formation of sufficient MA. Furthermore, the ferrite of the steel plate may not include acicular ferrite. Since the difference in hardness between acicular ferrite and MA is small, acicular ferrite does not guarantee a sufficient low yield ratio.

[0049] When the fraction of MA is less than 8%, it is difficult to obtain a low yield ratio with the range of 0.65 or less, and when the fraction of MA is greater than 20%, impact toughness may decrease, and elongation may decrease. In addition, if the average size of MA measured in equivalent circular equivalent is greater than 3 μm, MA is mainly formed along grain boundaries, thereby making it difficult to guarantee a uniform distribution of MA and a low yield ratio.

[0050] Inevitable phases other than the ferrite and MA may be included in the steel plate, and these phases may not be excluded. For example, pearlite may be included in the steel plate in an area% of 1 or less.

[0051] In this case, in order to guarantee low yield ratio characteristics and low temperature toughness, in addition to adjusting the fraction and size of MA as described above, it is preferable that when a 100-μm-long straight line is drawn on the steel plate of the present disclosure, MA be present on five to thirteen sites on the straight line.

[0052] That is, when several straight line are vertically or horizontally drawn on a microstructure photograph having a size of 100 μm × 100 μm, MA may be present at five to thirteen sites on each straight line on average. MA formed along grain boundaries mainly leads to the start of fracture, and when the above-described condition is satisfied, a low yield ratio may be obtained because the distribution of MA is uniform along grain boundaries and in grains.

[0053] In addition, the ratio of MA existing in ferrite grains to MA existing along ferrite grain boundaries may be 1:3 to 1:10. The ratio refers to the ratio of the numbers of MA sites, and when the ratio is within the above-mentioned range, MA may uniformly exist in ferrite grains in an amount of 0.5 area% to 5 area%.

[0054] In addition, the ferrite of the steel plate may have an average size measured in equivalent circular diameter within the range of 20 μm or less. If the average size of ferrite exceeds 20 μm, it may be difficult to ensure sufficient toughness and strength.

[0055] Meanwhile, the steel plate of the present disclosure is a steel plate treated by a normalizing heat treatment, and the microstructure of the steel plate before the normalizing heat treatment may have bainite in an amount of 50 area% to 90 area%.

[0056] Since the microstructure of the steel plate before the heat treatment has bainite in which carbides are contained, MA may be uniformly distributed along grain boundaries and in grains after the heat treatment. Thus, it is preferable that the microstructure of the steel plate before the heat treatment have bainite in an amount of 50 area% to 90 area%.

[0057] In addition, the steel plate of the present disclosure may have a yield ratio within the range of 0.5 to 0.65 and a low temperature impact property within the range of 100 J or greater at -40°C. Since the steel plate has a yield ratio within the range of 0.65 or less, that is, has a great difference between yield strength and tensile strength, the steel plate may have high formability, and the start of plastic deformation of the steel plate may be delayed until fracture may occur such that collapse caused by external force may be prevented owing to absorption of energy during the delay.

[0058] Therefore, the steel plate may be applied not only to shipbuilding and marine structures but also to industrial fields requiring formability and seismic resistance.

[0059] In this case, the steel plate may have a yield strength within the range of 350 MPa to 400 MPa and a tensile strength within the range of 600 MPa or greater.

[0060] Hereinafter, a method for manufacturing a high strength steel plate having low yield ratio characteristics and low temperature toughness will be described in detail according to another aspect of the present disclosure.

[0061] According to the other aspect of the present disclosure, the method for manufacturing a high strength steel plate having low yield ratio characteristics and low temperature toughness includes: heating a slab having the above-described alloy composition to 1050°C to 1200°C; hot rolling the heated slab such that a finish rolling termination temperature ranges from 760°C to 850°C, so as to obtain a hot-rolled steel plate; cooling the hot-rolled steel plate to 450°C or less at a cooling rate of 5°C/s or greater; and performing a normalizing heat treatment by heating the cooled hot-rolled steel plate to a temperature range of 850°C to 960 °C and then maintaining the steel plate for [1.3t + (10 to 30)] minutes. Here, t refers to the thickness of the steel plate measured in millimeters (mm) .

Heating Slab

[0062] A slab having the above-described alloy composition is heated to a temperature of 1050°C to 1200°C.

[0063] If the heating temperature is higher than 1200 °C, austenite grains may be coarsened to cause a decrease in toughness, and if the heating temperature is lower than 1050 °C, elements such as Ti and Nb may not be sufficiently dissolved to cause a decrease in strength.

Hot Rolling

[0064] The heated slab is hot rolled such that a finish rolling termination temperature may range from 760°C to 850°C, so as to obtain a hot-rolled steel plate.

[0065] In general, a normal rolling process is performed on heat-treated steel materials at a rolling temperature of 850°C to 1000°C. However, in the present disclosure, bainite is formed as an initial microstructure. Thus, instead of a general rolling process resulting in a ferrite-pearlite microstructure, a controlled rolling process is required to finish rolling at a low temperature.

[0066] Recrystallization rolling is required during the hot rolling process to obtain fine austenite grains, and as the reduction ratio per pass increases, physical properties may be improved.

[0067] It is required to finish unrecrystallized region rolling at a temperature equal to or greater than the Ar3 temperature of the steel material, that is, at a temperature of about 760°C or greater. More specifically, the finish rolling termination temperature may be set to be 760°C to 850°C. If the finish rolling termination temperature exceeds 850°C, it is difficult to suppress ferrite-pearlite transformation. If the finish rolling termination temperature is less than 760°C, a non-uniform microstructure may be formed in a thickness direction, and an intended microstructure may not be formed because of a decrease in rolling force by rolling roll loads.

[0068] The finish rolling is terminated at a temperature of 760°C to 850°C to suppress ferrite-pearlite transformation and form bainite by cooling. Bainite is formed as an initial microstructure to obtain uniform distribution of MA after a heat treatment. In a ferrite-pearlite microstructure, MA is mainly formed along grain boundaries whereas in a bainite microstructure, MA is formed along grain boundaries and in grains as well.

Cooling

[0069] The hot-rolled steel plate is cooled to a temperature of 450°C or less at a cooling rate of 5°C/s or greater.

[0070] Accelerated cooling after hot rolling is required to form an intended microstructure in inventive steel. Bainite is required to obtain fine and uniform MA, and the termination temperature and rate of the cooling are adjusted to form bainite.

[0071] If the cooling termination temperature is higher than 450 °C, coarse grains may be formed, and coarse MA may be formed after a heat treatment because of coarse carbides, causing a decrease in toughness and making it difficult to form bainite in an amount of 50 area% or greater.

[0072] If the cooling rate is less than 5°C / s, acicular ferrite or a ferrite+pearlite microstructure may be formed in large amounts to result in a decrease in strength; the formation of a coarse ferrite+pearlite microstructure instead of the formation of a two-phase microstructure of ferrite+MA or a sharp decrease in the amount of a second phase may be resulted after a heat treatment; and it is difficult to form bainite in an amount of 50 area% or greater.

Normalizing Heat Treatment

[0073] The cooled hot-rolled steel plate is heated to a temperature of 850°C to 960 °C, and then maintained for [1.3t + (10 to 30)] minutes. Here, t refers to the thickness of the steel plate measured in millimeters (mm).

[0074] If the normalizing temperature is less than 850°C or the maintaining period of time is less than (1.3t + 10) minutes, cementite and MA may not easily dissolve in pearlite and bainite, and thus the amount of dissolved carbon (C) may decrease. Therefore, it is difficult to guarantee strength, and a finally remaining hardened phase is coarse.

[0075] Conversely, if the normalizing temperature exceeds 960°C or the maintaining period of time is greater than (1.3t + 30) minutes, all the carbides existing in bainite grains may move to grain boundaries or carbide coarsening may occur. Thus, final MA may not have an intended size and may not be uniformly distributed. In addition, grain growth may occur to result in a decrease in strength and deterioration of impact characteristics.

[Mode for Invention]

[0076] Hereinafter, the present disclosure will be described more specifically through examples. However, the following examples should be considered in a descriptive sense only and not for purposes of limitation. The scope of the present invention is defined by the appended claims, and modifications and variations may be reasonably made therefrom.

[0077] Slabs were prepared by performing a continuous casting process on molten steel having the compositions shown in Table 1 below. Steel plates were manufactured by performing rolling, cooling, and normalizing heat treatment processes on the slabs under the manufacturing conditions shown in Table 2 below.

[0078] Table 3 shows the bainite fraction and mechanical properties of each of the steel plates measured before the normalizing heat treatment process.

[0079] After the normalizing heat treatment process, the MA fraction, the average MA size, the number of MA sites on a 100-μm long line, and the mechanical properties of each of the steel plates were measured as shown in Table 4. In inventive examples, ferrite was formed in addition to MA, and the average grain size of the ferrite was 20 μm or less (not recorded).

[0080] The average MA size refers to an equivalent circular diameter, and the number of MA sites on a 100-μm lone line was measured by vertically or horizontal drawing ten straight lines on a microstructure photograph having a size of 100 μm × 100 μm, counting the number of MA sites on each of the straight lines, and averaging the numbers.

[0081] Specifically, effects by rolling temperature, cooling termination temperature, heat treatment time were investigated. In Table 3, the MA fraction, the yield ratio, and the mechanical properties of each of the steel plates having compositions A to H and produced by manufacturing conditions 1 to 12 are shown.

[Table 1]

Class	Steels	C	Si	Mn	P	S	Al	Ni	Mo	Ti	Nb	Cu	N
IS	A	0.045	0.086	1.87	0.005	0.002	0.006	1.19	0.13	0.007	0.008	0.242	0.0037
IS	B	0.04	0.095	1. 92	0.004	0.0017	0.012	1.21	0.15	0.01	0.01	0.235	0.004
IS	C	0.043	0.105	1.88	0.005	0.0018	0.01	1.18	0.15	0.009	0.011	0.248	0.0038
IS	D	0.046	0.095	1.91	0.005	0.0018	0.011	1.21	0.16	0.008	0.01	0.251	0.0035
CS	E	**0.12**	0.12	1.87	0.005	0.0018	0.011	1.21	0.14	0.011	0.01	0.241	0.0035
CS	F	0.037	0.11	1.91	0.005	0.0017	0.013	1.21	**0.012**	0.012	0.012	0.253	0.0037

(continued)

Class	Steels	C	Si	Mn	P	S	Al	Ni	Mo	Ti	Nb	Cu	N
CS	G	0.04	0.11	**0.85**	0.0048	0.0017	0.012	1.17	0.13	0.01	0.012	0.255	0.0035
CS	H	0.042	0.13	1.88	0.0047	0.0018	0.01	**0.23**	0.12	0.01	0.011	0.239	0.0037
*IS: Inventive Steel, CS: Comparative Steel													

[0082] In Table 1, the content of each element is given in wt%. Inventive steels A to D were used to prepare steel plates satisfying the component ranges proposed in the present disclosure, and comparative steels E to H do were used to prepare steel plates not satisfying the component ranges proposed in the present disclosure. Comparative steel E had an excessive C content, comparative steel F lacked an Mo content, comparative steel G lacked an Mn content, and comparative steel H lacked a Ni content.

[Table 2]

Class	Test No.	Steels	Reheating temp. (°C)	Finish rolling start temp. (°C)	Finish rolling termination temp. (°C)	Coolingtermination temp. (°C)	Cooling rate (°C/s)	Normalizing temp. (°C)	Normalizing time (minutes)
*IE	1	A	1151	813	799	329	9.8	910	85
IE	2	A	1146	795	781	337	10.5	910	90
IE	3	B	1138	805	784	332	10.4	910	92
IE	4	B	1146	804	787	342	10.8	910	90
IE	5	C	1143	820	778	384	8.9	875	91
**CE	6	C	1175	965	**923**	348	11.2	910	88
CE	7	C	1116	802	783	-	-	910	95
IE	8	D	1139	812	791	356	11.1	884	86
CE	9	D	1124	809	778	325	10.6	910	**240**
CE	10	D	1135	798	778	**652**	9.7	910	89
CE	11	E	1145	812	801	335	9.9	910	85
CE	12	F	1125	790	773	322	10.3	910	96
CE	13	G	1135	795	781	365	11.1	910	83
CE	14	H	1128	786	768	341	10.2	910	98
*IE: Inventive Example, **CE: Comparative Example									

[Table 3]

Class	Test No.	Steels	Before normalizing heat treatment				
			Bainite (area%)	Yield strength (MPa)	Tensile strength (MPa)	Yield ratio	Elongation (%)
*IE	1	A	62	541	613	0.88	25.5
IE	2	A	72	521	631	0.83	23
IE	3	B	63	510	637	0.80	22
IE	4	B	83	510	636	0.80	21
IE	5	C	76	524	628	0.83	22.3
**CE	6	C	<u>11</u>	488	593	0.82	23.4
CE	7	C	<u>0</u>	445	556	0.80	26.2
IE	8	D	77	531	632	0.84	23.1
CE	9	D	68	514	647	0.79	27.3
CE	10	D	<u>8</u>	568	652	0.87	21.4
CE	11	E	<u>3</u>	489	584	0.84	23.7
CE	12	F	<u>28</u>	481	573	0.84	24.8
CE	13	G	<u>24</u>	487	562	0.86	22.7
CE	14	H	<u>19</u>	502	604	0.83	21.8
*IE: Inventive Example, **CE: Comparative Example							

[Table 4]

Class	Test No.	Steels	After normalizing heat treatment							
			MA fraction (area%)	Average MA size (μm)	Number of MA sites on 100-μm-long line	Yield strength (MPa)	Tensile strength (MPa)	Yield ratio	Elongation (%)	Impact toughness (-40°C) (J)
*IE	1	A	12.5	2.3	7.2	354	617	0.57	30.7	163
IE	2	A	11.4	1.8	9.3	357	621	0.57	30.5	181.8
IE	3	B	9.8	2.6	6.3	355	617	0.58	28.4	167
IE	4	B	10.2	1.9	8.2	359	619	0.58	31.6	108.6
IE	5	C	12.5	2.8	8.1	378	625	0.6	29.6	102.5
**CE	6	C	2.3	5.2	2.4	471	568	0.83	27.6	67.8
CE	7	C	3.4	6.1	0.5	452	548	0.82	28	57.6
IE	8	D	13.5	2.2	12.4	384	635	0.6	29.4	123.9
CE	9	D	1.2	5.3	2.2	482	574	0.84	28.1	42.3
CE	10	D	2.6	4.9	1.6	506	624	0.81	24.5	21.5
CE	11	E	1.2	5.1	1.5	462	571	0.81	25.4	98.4
CE	12	F	3.5	3.9	2.8	423	538	0.79	26.7	103.4
CE	13	G	2.3	4.2	3.6	416	557	0.75	25.9	116.3
CE	14	H	2.6	4.6	2.5	426	574	0.74	26.1	35.6

*IE: Inventive Example, **CE: Comparative Example

[0083] The inventive examples satisfying all of the alloy composition and the manufacturing conditions proposed in the present disclosure have a yield ratio of 0.65 or less and an impact toughness of 100 J or greater at -40°C.

[0084] Test Nos. 6, 7, 9, and 10 (comparative examples) satisfied the alloy composition proposed in the present disclosure, but did not satisfy the manufacturing conditions proposed in the present disclosure. Thus, test Nos. 6, 7, 9, 10 failed to guarantee a sufficiently low yield ratio and had poor impact toughness at -40°C within the range of less than 100 J.

[0085] Test Nos. 11 to 14 (comparative examples) satisfied the manufacturing conditions proposed in the present disclosure, but did not satisfy the alloy composition proposed in the present disclosure. Thus, test Nos. 11 to 14 failed to guarantee a sufficiently low yield ratio, and the impact toughness of test Nos. 11 and 14 was poor within the range of less than 100 J at -40°C.

[0086] As shown in Table 4, the MA fractions in the inventive examples are greater than those in the comparative examples. The reason for this is that: since the fraction of bainite was high before the normalizing heat treatment process as shown in Table 3 above, carbides existing in grains and along grain boundaries of the initial bainite were transformed into fine MA.

[0087] Referring to FIGS. 1 and 2 showing images of the microstructure of test No 1 (inventive example), the formation of fine and uniform MA can be seen.

[0088] However, referring to FIG. 3 showing an image of the microstructure of test No. 12, carbides and pearlite are present as main two phases, the fraction of MA is low, and the MA has a polygonal shape and mainly exists along grain boundaries.

[0089] While 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 invention as defined by the appended claims.

Claims

1. A high strength steel plate having low yield ratio characteristics and low temperature toughness comprises, by wt%, C: 0.03% to 0.08%, Si: 0.05% to 0.3%, Mn: 1.0% to 2.0%, Al: 0.005% to 0.04%, Nb: 0.005% to 0.04%, Ti: 0.001% to 0.02%, Cu: 0.05% to 0.4%, Ni: 0.6% to 2.0%, Mo: 0.08% to 0.3%, N: 0.002% to 0.006%, P: 0.01% or less, S: 0.003% or less, and a balance of Fe and inevitable impurities,
   wherein a microstructure of the high strength steel plate comprises, by area%, ferrite in an amount of 80% to 92% and MA (a mixed structure of martensite/austenite) in an amount of 8% to 20%, and the MA has an average size of 3 μm or less when measured in equivalent circular diameter.

2. The high strength steel plate of claim 1, wherein when a 100-μm-long straight line is drawn on the high strength steel plate, five to thirteen MA sites are present on the 100-μm-long straight line.

3. The high strength steel plate of claim 1, wherein a ratio of MA existing in ferrite grains and MA existing along ferrite grain boundaries ranges from 1:3 to 1:10.

4. The high strength steel plate of claim 1, wherein the ferrite has an average size of 20 μm or less measured in equivalent circular diameter.

5. The high strength steel plate of claim 1, wherein the high strength steel plate is a steel plate treated by a normalizing heat treatment, and
   before the normalizing heat treatment, the microstructure of the high strength steel plate comprises bainite in an amount of 50 area% to 90 area%.

6. The high strength steel plate of claim 1, wherein the high strength steel plate has a yield ratio of 0.5 to 0.65 and a low temperature impact property of 100 J or greater at -40°C.

7. The high strength steel plate of claim 1, wherein the high strength steel plate has a strength of 350 MPa to 400 MPa and a tensile strength of 600 MPa or greater.

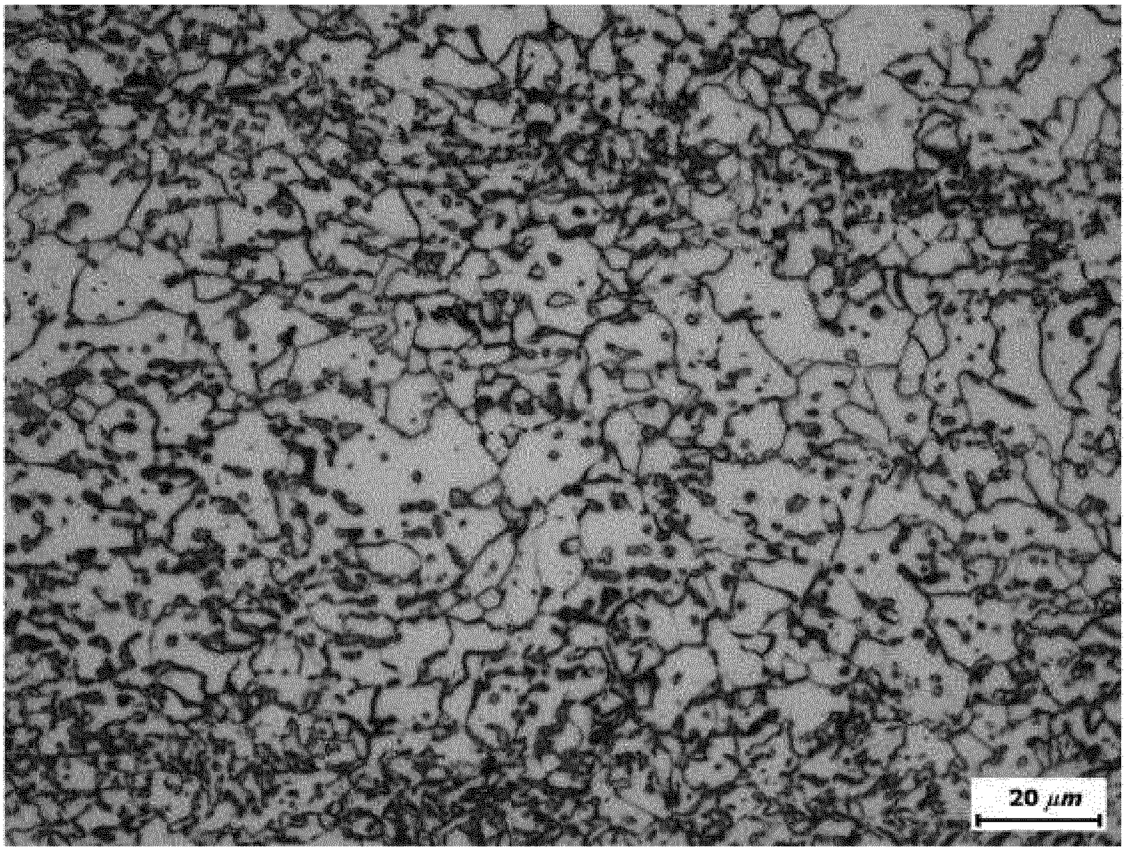
8. A method for manufacturing a high strength steel plate having low yield ratio characteristics and low temperature toughness, the method comprising:

   heating a slab to a temperature of 1050°C to 1200°C, the slab having, by wt%, C: 0.03% to 0.08%, Si: 0.05%

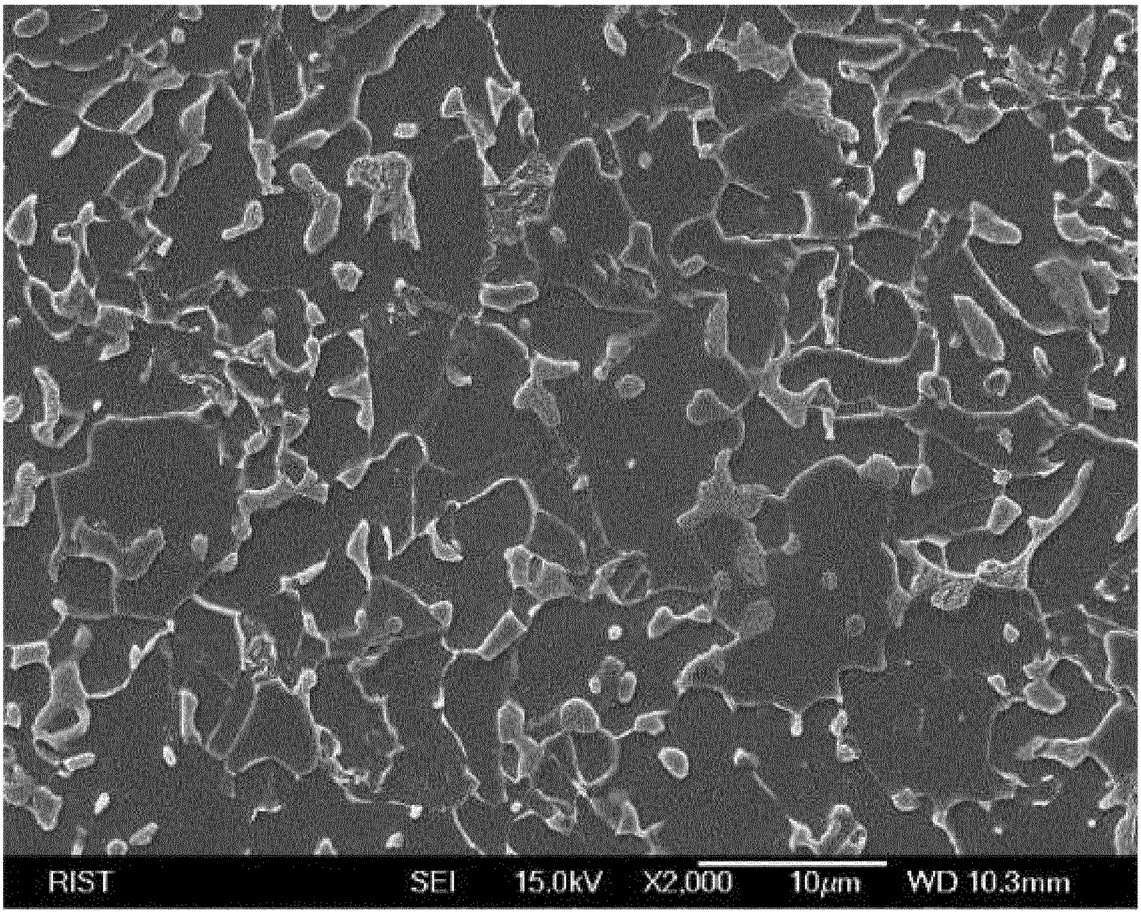
to 0.3%, Mn: 1.0% to 2.0%, Al: 0.005% to 0.04%, Nb: 0.005% to 0.04%, Ti: 0.001% to 0.02%, Cu: 0.05% to 0.4%, Ni: 0.6% to 2.0%, Mo: 0.08% to 0.3%, N: 0.002% to 0.006%, P: 0.01% or less, S: 0.003% or less, and a balance of Fe and inevitable impurities;
hot rolling the heated slab in such a manner that a finish rolling termination temperature ranges from 760°C to 850°C, so as to obtain a hot-rolled steel plate;
cooling the hot-rolled steel plate to a temperature of 450°C or less at a cooling rate of 5°C/s or greater; and
after heating the cooled hot-rolled steel plate to a temperature of 850°C to 960°C, maintaining the hot-rolled steel plate for [1.3t+(10~30)] minutes where t refers to a thickness of the hot-rolled steel plate in millimeters (mm).

9. The method of claim 8, wherein the cooled hot-rolled steel plate has a microstructure comprising bainite in an amount of 50 area% to 90 area%.

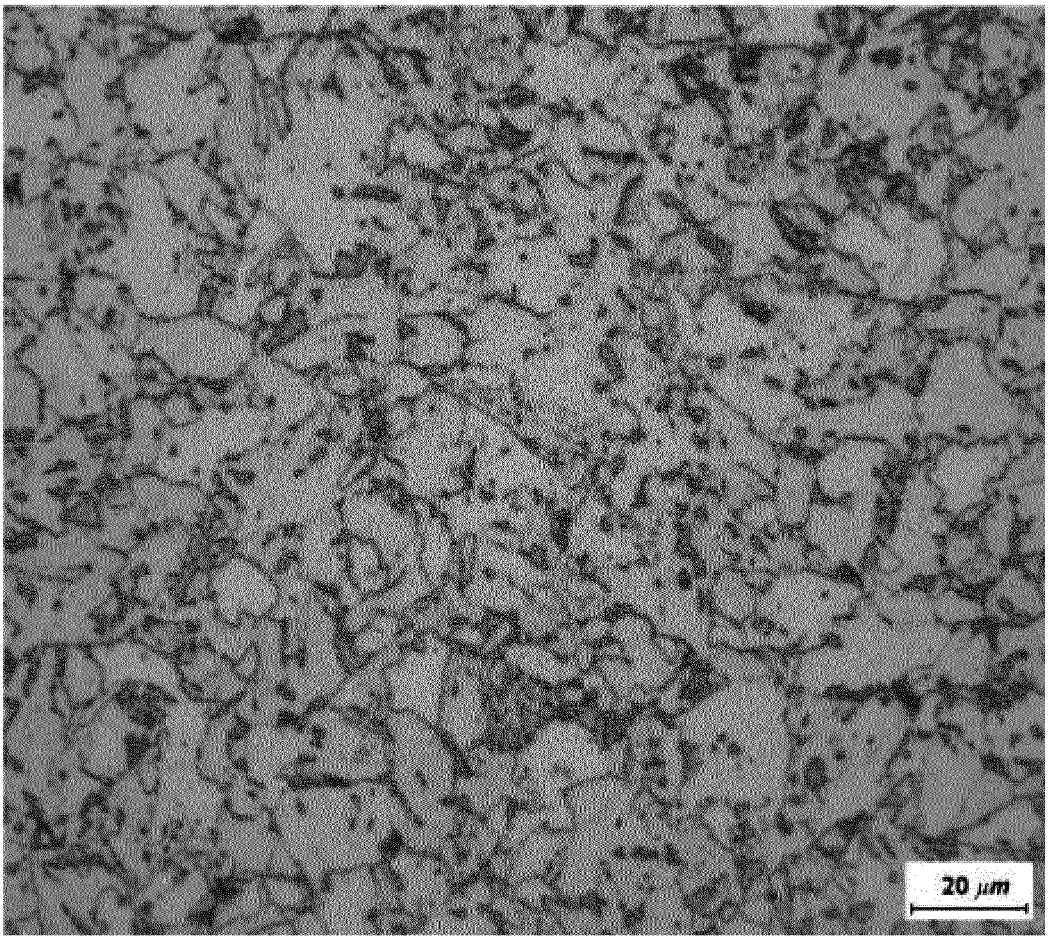
【Figure 1】



【Figure 2】



【Figure 3】



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2017/006956

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/00(2006.01)i, C22C 38/02(2006.01)i, C22C 38/04(2006.01)i, C22C 38/06(2006.01)i, C22C 38/08(2006.01)i, C22C 38/12(2006.01)i, C22C 38/14(2006.01)i, C22C 38/16(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 38/00; C21D 6/00; C21D 1/30; C21D 8/02; C22C 38/02; C22C 38/04; C22C 38/06; C22C 38/08; C22C 38/12; C22C 38/14; C22C 38/16; 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: low yield ratio, micro structure, mixed structure, MA, tensile strength, yield strength, normalizing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 07-278656 A (NIPPON STEEL CORP.) 24 October 1995 See paragraphs [0006]-[0008], [0011], [0019]-[0025], claims 1-3 and tables 1-3.	1-9
A	KR 10-1482359 B1 (POSCO) 13 January 2015 See paragraphs [0053]-[0055] and claims 1-2, 4, 7.	1-9
A	KR 10-2014-0118313 A (HYUNDAI STEEL COMPANY) 08 October 2014 See paragraphs [0062]-[0065] and claims 1-4.	1-9
A	JP 09-256037 A (NIPPON STEEL CORP.) 30 September 1997 See claims 1-2 and table 1.	1-9
A	JP 2003-003229 A (NIPPON STEEL CORP.) 08 January 2003 See paragraph [0064], claims 1-5 and table 1.	1-9

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

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"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
12 SEPTEMBER 2017 (12.09.2017)	**14 SEPTEMBER 2017 (14.09.2017)**

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2017/006956

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REFERENCES CITED IN THE DESCRIPTION

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