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(54) **LOW-YIELD-RATIO TYPE HIGH-STRENGTH STEEL, AND MANUFACTURING METHOD THEREFOR**

(57) One aspect of the present invention relates to a low-yield-ratio type high-strength steel comprising 0.02-0.11 wt% of carbon (C), 0.1-0.5 wt% of silicon (Si), 1.5-2.5 wt% of manganese (Mn), 0.01-0.06 wt% of aluminum (Al), 0.1-0.6 wt% of nickel (Ni), 0.01-0.03 wt% of titanium (Ti), 0.005-0.08 wt% of niobium (Nb), 0.1-0.5 wt% of chromium (Cr), 0.01 wt% or less of phosphorus

(P) (excluding 0 wt%), 0.01 wt% or less of sulfur (S) (excluding 0 wt%), 5-30 weight ppm of boron (B), 20-70 weight ppm of nitrogen (N), 50 weight ppm or less of calcium (Ca) (excluding 0 weight ppm), 5-50 weight ppm or less of tin (Sn) (excluding 0 weight ppm), and the remainder being iron (Fe) and other inevitable impurities.

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Description

[Technical Field]

5 **[0001]** The present disclosure relates to low-yield-ratio type, high-strength steel and a manufacturing method therefor, and more particularly, to low-yield-ratio type, high-strength steel that is appropriate for use as steel for construction due to a low yield ratio and high tensile strength, and a manufacturing method therefor.

[Background Art]

10 **[0002]** Recently, according to the trend for extremely tall and long span structures, such as domestic and foreign buildings and bridges, there has been a need to develop extra thick high strength steel. When high strength steel is used, the structures of buildings and bridges are rationalized and lightened due to high allowable stress of the high strength steel and, thus, economical construction is possible and a plate thickness is reduced, thereby allowing machining
15 such as cutting or perforation and welding operations to be easily performed.

[0003] When the strength of steel is increased, a yield ratio (yield strength/tensile strength) that is a ratio of tensile strength to yield strength is frequently increased. In this regard, when a yield ratio is increased, a stress difference up to a point in time at which deconstruction occurs from a point in time (yield point) at which plastic deformation occurs is not high and, thus, buildings have a low construction margin for preventing buildings from disintegrating through absorbing energy via deformation and, accordingly, when a large external force, such as that of an earthquake is applied, there is
20 a problem in that it is difficult to ensure safety. Accordingly, steel for construction needs to satisfy both high strength and low yield ratio.

[0004] In general, it is well known that a yield ratio of steel is lowered by realizing a structure in which a metal structure of steel including a soft phase material such as ferrite as a major structure and a hard phase material such as bainite or martensite is appropriately distributed.
25

[0005] To acquire a structure in which a hard phase material is appropriately distributed in the above soft phase-based refined structure, Patent Document 1 discloses a method of lowering a yield ratio via appropriate quenching and tempering in a dual phase region of ferrite and austenite. However, the method requires an additional number of thermal treatment processes in addition to a rolling manufacturing process and, thus, there is a problem in that it is inevitable to reduce
30 productivity and to increase manufacturing costs.

[0006] Accordingly, there has been a need to develop low-yield-ratio type, high-strength steel and a manufacturing method therefor, for ensuring super high strength and low yield ratio as well as overcoming the problem in terms of reduced productivity, increased manufacturing costs, etc.

[Cited Reference]

[0007] (Patent Document 1) Japanese Patent Laid-Open Publication No. sho 55-97425

[Disclosure]

40 [Technical Problem]

[0008] An aspect of the present disclosure is to provide low-yield-ratio type, high-strength steel and a manufacturing method therefor, and in detail, low-yield-ratio type, high-strength steel and a manufacturing method therefor, for ensuring
45 super high strength and a low yield ratio without reduction in productivity and increase in manufacturing costs.

[0009] The objective of the present disclosure is not limited to the above description and the following detailed description of the present disclosure are exemplary and explanatory and are intended to provide further explanation of the feature as claimed by one of ordinary skill in the art without undue difficulty.

[Technical Solution]

[0010] According to an aspect of the present disclosure, low-yield-ratio type, high-strength steel includes 0.02 to 0.11 wt% of carbon (C), 0.1 to 0.5 wt% of silicon (Si), 1.5 to 2.5 wt% of manganese (Mn), 0.01 to 0.06 wt% of aluminum (Al), 0.1 to 0.6 wt% of nickel (Ni), 0.01 to 0.03 wt% of titanium (Ti), 0.005 to 0.08 wt% of niobium (Nb), 0.1 to
55 0.5 wt% of chromium (Cr), 0.01 wt% or less of phosphorus (P) (excluding 0 wt%), 0.01 wt% or less of sulfur (S) (excluding 0 wt%), 5 to 30 wt ppm of boron (B), 20 to 70 wt ppm of nitrogen (N), 50 wt ppm or less of calcium (Ca) (excluding 0 wt ppm), 5 to 50 wt ppm or less of tin (Sn) (excluding 0 wt ppm), iron (Fe) as a remainder thereof, and other inevitable impurities.

[0011] According to another aspect of the present disclosure, a method of manufacturing low-yield-ratio type, high-strength steel includes heating a slab including 0.02 to 0.11 wt% of carbon (C), 0.1 to 0.5 wt% of silicon (Si), 1.5 to 2.5 wt% of manganese (Mn), 0.01 to 0.06 wt% of aluminum (Al), 0.1 to 0.6 wt% of nickel (Ni), 0.01 to 0.03 wt% of titanium (Ti), 0.005 to 0.08 wt% of niobium (Nb), 0.1 to 0.5 wt% of chromium (Cr), 0.01 wt% or less of phosphorus (P), 0.01 wt% or less of sulfur (S), 5 to 30 wt ppm of boron (B), 20 to 70 wt ppm of nitrogen (N), 50 wt ppm or less of calcium (Ca) (excluding 0), 5 to 50 wt ppm or less of tin (Sn), a balance thereof, being iron (Fe), and other inevitable impurities, at 1050 to 1250, rough-rolling the heated slab at 950 to 1150°C to acquire a bar, hot-rolling the bar at final rolling temperature of 700 to 950°C to acquire hot rolled steel, and cooling the hot rolled steel at cooling speed of 25 to 50°C/s up to cooling termination temperature of Bs or less.

[0012] The objective of the present disclosure is not limited to the above description and various features and advantages thereof are understood will be more clearly understood from the following detailed description.

[Advantageous Effects]

[0013] As set forth above, according to an exemplary embodiment in the present disclosure, low-yield-ratio type, high-strength steel and a manufacturing method therefor may ensure extra high strength and a low yield ratio without reduction in productivity and increase in manufacturing costs.

[Best Mode for Invention]

[0014] Exemplary embodiments of the present disclosure will now be described more fully. The exemplary embodiments of present disclosure may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the feature to those skilled in the art.

[0015] Hereinafter, low-yield-ratio type, high-strength steel according to an aspect of the present disclosure is described in detail.

[0016] The low-yield-ratio type, high-strength steel according to an aspect of the present disclosure may include 0.02 to 0.11 wt% of carbon (C), 0.1 to 0.5 wt% of silicon (Si), 1.5 to 2.5 wt% of manganese (Mn), 0.01 to 0.06 wt% of aluminum (Al), 0.1 to 0.6 wt% of nickel (Ni), 0.01 to 0.03 wt% of titanium (Ti), 0.005 to 0.08 wt% of niobium (Nb), 0.1 to 0.5 wt% of chromium (Cr), 0.01 wt% or less of phosphorus (P) (excluding 0 wt%), 0.01 wt% or less of sulfur (S) (excluding 0 wt%), 5 to 30 wt ppm of boron (B), 20 to 70 wt ppm of nitrogen (N), 50 wt ppm or less of calcium (Ca) (excluding 0 wt ppm), 5 to 50 wt ppm or less of tin (Sn) (excluding 0 wt ppm), a balance thereof, being iron (Fe), and other inevitable impurities.

Carbon (C): 0.02 to 0.11 wt%

[0017] C is an important element for forming bainite or martensite and determining a size and fraction of the formed bainite or martensite.

[0018] When a content of C is greater than 0.11 wt%, low temperature toughness may be lowered and, when a content of C is less than 0.02 wt%, formation of bainite or martensite may be obstructed to degrade strength. Accordingly, content of C may be 0.02 to 0.11 wt%.

[0019] For high weldability of a plate used as a steel structure for welding, an upper limit of content of C may be 0.08 wt%.

Silicon (Si): 0.1 to 0.5 wt%

[0020] Si is an element used as a deoxidizer for enhancing strength and toughness.

[0021] When a content of Si is greater than 0.5 wt%, low temperature toughness and weldability may be lowered and thick scale is formed on a plate surface to cause gas cuttability defects, other surface cracks, and so on. On the other hand, when a content of Si is less than 0.1 wt%, a deoxidation effect may be insufficient. Accordingly, a content of Si may be 0.1 to 0.5 wt% and, more particularly, 0.15 to 0.35 wt%.

Manganese (Mn): 1.5 to 2.5 wt%

[0022] Mn may be an element useful to enhance strength via solid-solution strengthening and, thus, it is necessary to add 1.5 wt% or more of Mn. However, when a content of Mn is greater than 2.5 wt%, toughness of a welding portion may be largely lowered due to excessive increase in hardenability. Accordingly, a content of Mn may be 1.5 to 2.5 wt%.

Aluminum (Al): 0.01 to 0.06 wt%

[0023] Al may be an element that inexpensively deoxidizes molten steel and stabilizes ferrite. When a content of Al is less than 0.01 wt%, the aforementioned effect may be insufficient. On the other hand, when a content of Al is greater than 0.06 wt%, a nozzle may clog in the case of continuous casting. Accordingly, a content of Al may be 0.01 to 0.06 wt%.

Nickel (Ni): 0.1 to 0.6 wt%

[0024] Ni may be an element that simultaneously enhances strength and toughness of a parent material. According to the present disclosure, to acquire the aforementioned effect, 0.1 wt% or more of Ni may be added. However, Ni is an expensive element and, thus, when Ni is added in an amount greater than 0.6 wt%, economization may be reduced and weldability may be lowered. Accordingly, content of Ni may be 0.1 to 0.6%.

Titanium (Ti): 0.01 to 0.03 wt%

[0025] Ti prevents growth of crystal grain while being reheated to largely enhance low temperature toughness and, thus, 0.01 wt% or more of Ti may be added. However, when a content of Ti is greater than 0.03 wt%, there may be a problem in terms of a reduction in low temperature toughness due to clogging of a nozzle for continuous casting or crystallization of a central portion. Accordingly, content of Ti may be 0.01 to 0.03 wt%.

Niobium (Nb): 0.005 to 0.08 wt%

[0026] Nb may be an important element for manufacturing TMCP steel and is precipitated in the form of NbC or NbCN to enhance strength of a parent material and a welding portion. Nb that is solid-solved while being reheated at high temperature prevents re-crystallization of austenite and modification of ferrite or bainite to refine a structure. Furthermore, according to the present disclosure, bainite may be formed even at low cooling speed when a slab is cooled after rough rolling is performed, and stability of austenite may also be enhanced when a slab is cooled after last rolling is performed and, accordingly, generation of martensite may also be facilitated in the case of cooling at low speed.

[0027] To sufficiently acquire the aforementioned effect, content of Nb may be 0.005 wt% or more. However, when a content of Nb is greater than 0.08 wt%, brittleness crack may occur at an edge of steel. Accordingly, content of Nb may be 0.005 to 0.08 wt%.

Chromium (Cr): 0.1 to 0.5 wt%

[0028] To acquire strength, Cr may be an element added to ensure strength and may enhance quenching property. To sufficient the aforementioned effect, it may be required to add 0.1% or more of Cr. However, when a content of Cr is greater than 0.5%, rigidity of a welding portion may be excessively increased and toughness may be degraded. Accordingly, content of Cr may be 0.1 to 0.5%.

Phosphorus (P): 0.01 wt% or less

[0029] P may be an element that is advantageous for enhancing strength and anti-corrosion but largely obstructs impact toughness and, thus, content of P may be advantageously lowered and, thus, an upper content limit of P may be 0.01 wt%.

Sulfur (S): 0.01 wt% or less

[0030] S may be an element that forms MnS or the like and largely obstructs impact toughness and, thus, content of S may be advantageously lowered and an upper content limit of S may be 0.01 wt%.

Boron (B): 5 to 30 wt ppm

[0031] B may be a much inexpensive element indicating high hardenability and may be an element that is largely useful to form bainite at low speed when being cooled after rough rolling is performed.

[0032] By simply adding a small amount of B, strength may be largely enhanced and, thus, 5 wt ppm or more of B may be added. However, when a content of B is greater than 30 wt ppm, $\text{Fe}_{23}(\text{CB})_6$ may be formed to rather reduce hardenability and to largely reduce low temperature toughness. Accordingly, content of B may be 5 to 30 wt ppm.

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Nitrogen (N): 20 to 70 wt ppm

[0033] N enhances strength but largely reduces toughness and, thus, content of N may be controlled to be 70 wt ppm or less. However, when a content of N is controlled to be less than 20 wt ppm, steel manufacturing load is increased and, thus, a lower content limit of N may be 20 wt ppm.

Calcium (Ca): 60 wt ppm or less (excluding 0)

[0034] Ca may be used as an element that mainly prevents non-metallic inclusion of MnS and enhances low temperature toughness. However, when an excessive amount of Ca is added, Ca reacts with oxygen included in steel to generate CaO that is non-metallic inclusion and, thus, an upper content limit of Ca may be 60 wt ppm.

Tin (Sn): 5 to 50 wt ppm

[0035] Sn may be an important element for ensuring anti-corrosion.

[0036] In terms of ensuring of anti-corrosion, 5 ppm or more of Sn may be added. However, when a content of Sn is greater than 50 wt ppm, there may be a problem in terms of a lot of amount of defects in which a scale inflates or bursts like a blister on a steel surface rather than an effect of enhancing anti-corrosion. In addition, Sn enhances strength of steel but degrades elongation and low-temperature impact toughness and, thus, an upper content limit of Sn may be 50 wt ppm.

[0037] The remaining element in the present disclosure may be iron (Fe). However, unintended impurities from a material or a surrounding environment are inevitably introduced and, thus, the impurities are not capable of being disregarded. These impurities are known to one of ordinary skill in the art in a common manufacturing process and, thus, information on the impurities is not described throughout this specification.

[0038] Steel with the aforementioned advantageous steel composition may have a sufficient effect by simply including an alloy element with the aforementioned content range but properties such as strength and toughness of steel, and toughness and weldability of a welding heat affected zone may be further enhanced by further including one or more of 0.1 to 0.5 wt% of copper (Cu), 0.15 to 0.3 wt% of molybdenum (Mo), and 0.005 to 0.3 wt% of vanadium (V).

Copper (Cu): 0.1 to 0.5 wt%

[0039] Cu may be an element that minimizes reduction in toughness of a parent material and, simultaneously, enhances strength. To acquire the aforementioned effect, Cu of 0.1 wt% or more may be added. However, when a content of Cu is greater than 0.5 wt%, product surface properties may be largely degraded. Accordingly, content of Cu may be 0.1 to 0.5 wt%.

Molybdenum (Mo): 0.15 to 0.3 wt%

[0040] Even if a small amount of Mo is added, hardenability may be largely enhanced to enhance strength and, thus, it may be required to add 0.15 wt% or more of Mo. However, when Mo is added in an amount greater than 0.3 wt%, rigidity of a welding portion may be excessively increased and toughness may be degraded. Accordingly, a content of Mo may be 0.15 to 0.3 wt%.

Vanadium (V): 0.005 to 0.3 wt%

[0041] V is solid-solved at lower temperature than other refined alloy and is precipitated in a welding heat affected zone and prevent reduction in strength. To sufficiently acquire the aforementioned effect, 0.005 wt% or more of V may be added. However, when a content of V is greater than 0.3 wt%, toughness may be rather reduced. Accordingly, content of V may be 0.005 to 0.3 wt%.

[0042] The refined structure of the steel according to the present disclosure may include bainitic ferrite and granular bainite in a primary phase and include M-A (martensite austenite constituent) in a secondary phase.

[0043] Bainitic ferrite includes many high tilt boundaries in a grain while maintaining an initial austenite crystal grain system and, thus, may be useful to enhance strength and impact toughness by virtue of a crystal grain refining effect. Granular bainite maintains an initial austenite crystal grain like bainitic ferrite but a secondary phase such as M-A is present in a grain or a grain boundary. A high tilt boundary is not present in a grain boundary and, thus, it is disadvantageous for impact toughness but a large amount of low tilt boundaries are present like inter-grain electric potential and, thus, strength is slightly increased.

[0044] Bainitic ferrite and granular bainite are included in a primary phase and, thus, a low yield ratio and high strength

may be ensured.

[0045] In this case, in terms of an area fraction, the bainitic ferrite may be 80 to 95%, the granular bainite may be 5 to 20%, and the M-A may be 3% or less (including 0%).

[0046] When an area fraction of bainitic ferrite is less than 80%, it may be difficult to ensure high tensile strength and, when the area fraction is greater than 95%, there is a problem in terms of an increased yield ratio.

[0047] When an area fraction of granular bainite is less than 5%, yield strength as well as tensile strength may be increased and, thus, it is not possible to ensure a low yield ratio and, when the area fraction is greater than 20%, it may not be possible to effectively refine an initial coarsened austenite crystal grain and, thus, tensile strength may be degraded.

[0048] A secondary phase such as M-A may be a refined structure useful to achieve a low yield ratio and, thus, may have an area fraction of 3% or less. When the area fraction of M-A is greater than 3%, a yield ratio may be reduced but this may function as an initiation point of cracking with respect to external stress and, thus, it may adversely affect ensuring of tensile strength.

[0049] $Pl_{max.}(111)/Pl_{max.}(100)$ of steel according to the present disclosure may be 1.0 or more or 1.8 or less. The $Pl_{max.}(111)$ may be pole intensity ($Pl_{max.}$) of (111) crystalline surface acquired using a method such as X-ray diffraction or electron backscatter diffraction and the $Pl_{max.}(100)$ may be pole intensity ($Pl_{max.}$) of a (100) crystalline surface.

[0050] The pole intensity of the crystalline surface may be determined depending on a last refined structure of steel according to an aspect of the present disclosure. When bainitic ferrite and granular bainite are in a primary phase, as a fraction of bainitic ferrite is increased, a value of the $Pl_{max.}(111)$ is increased and, as a fraction of granular bainite is increased, a value of the $Pl_{max.}(100)$ may be increased. According to an aspect of the present disclosure, the last refined structure of the steel has bainitic ferrite with a higher area fraction than granular bainite and, when $Pl_{max.}(111)/Pl_{max.}(100)$ is equal to or less than 1.8, it may be possible to manufacture low-yield-ratio type, high-strength steel and, when $Pl_{max.}(111)/Pl_{max.}(100)$ is greater than 1.8, a low yield ratio may not be satisfied and, thus, an upper limit may be 1.8 or less. In detail, $Pl_{max.}(111)/Pl_{max.}(100)$ may be 1.6 or less.

[0051] When $Pl_{max.}(111)/Pl_{max.}(100)$ is less than 1.0, a fraction of granular bainite is increased to be greater than 20% and, thus, there is a problem in that it is difficult to ensure high strength. Accordingly, a lower limit of $Pl_{max.}(111)/Pl_{max.}(100)$ may be equal to or greater than 1.0 and, in more detail, may be 1.2 or more.

[0052] The steel according to the present disclosure may have a yield ratio of 0.85 or less and may ensure tensile strength of 800 MPa or more and, thus, the steel may be used as steel for construction, or the like.

[0053] The steel according to the present disclosure may have a thickness of 60 mm or less.

[0054] Since the steel according to the present disclosure may ensure high strength and a low yield ratio, the steel may have a plate thickness of 60 mm or less and, thus, it may be easy to perform machining such as cutting or perforation and a welding operation. Accordingly, the steel may have a thickness of 60 mm or less. In more detail, the thickness may be 40 mm or less and, more particularly, 30 mm or less.

[0055] A lower thickness limit of the steel may not be particularly limited but may be 15 mm or more to use the steel as steel for a construction structure.

[0056] Hereinafter, a manufacturing method of low-yield-ratio type, high-strength steel according to another aspect of the present disclosure is described in detail.

[0057] The manufacturing method of low-yield-ratio type, high-strength steel according to another aspect of the present disclosure may include heating a slab with the aforementioned alloy composition at 1050 to 1250°C, rough-rolling the heated slab at 950 to 1150°C to obtain a bar, hot-rolling the bar at final rolling temperature of 700 to 950 °C to acquire hot rolled steel, and cooling the hot rolled steel at cooling speed of 25 to 50°C /s up to cooling termination temperature of Bs or less.

Heating Slab

[0058] A slab having the aforementioned alloy composition may be heated to a temperature of 1050 to 1250°C.

Rough Rolling

[0059] The heated slab may be rough-rolled at 950 to 1050°C to acquire a bar.

[0060] When the rough rolling temperature is less than 950°C, as austenite is deformed in a state in which re-crystallization does not occur, there is a concern of coarsening of particles and, when the rough rolling temperature is greater than 1050°C, re-crystallization occurs and, simultaneously, particles are grown and, thus, there is also a concern of coarsening of austenite particles.

Hot-rolling

[0061] The bar is hot-rolled at final rolling temperature of 700 to 950°C to acquire hot rolled steel.

[0062] When the final rolling temperature is less than 700°C, a temperature of a plate is low and, thus, a load is generated in a rolling mill and there is a concern in that the plate is not capable of being rolled to a final thickness and, when the final rolling temperature is greater than 950°C, there is a concern of re-crystallization during rolling.

[0063] In this case, a reduction ratio of the hot rolling may be 50 to 80%.

[0064] When the final rolling reduction ratio is less than 50%, load applied to a material is increased during rolling and there is danger of facility accidents and, when the final rolling reduction ratio is greater than 80%, the number of rolling paths is increased and, thus, there is a concern of not ensuring a final thickness up to rolling termination temperature.

Cooling

[0065] The hot rolled steel may be cooled at cooling speed of 25 to 50°C/s up to cooling termination temperature of Bs or less.

[0066] When cooling of the hot rolled steel is terminated at temperature greater than Bs, a phase of bainitic ferrite and granular bainite is not sufficiently transitioned and, thus, strength is not capable of being ensured. A cooling speed has a physical limit depending on a plate thickness but, as soft ferrites are generated at a cooling speed less than 25°C/s, it may be difficult to satisfy tensile strength of 800 MPa or more. As the possibility that martensite which is low temperature transformed structure is generated at cooling speed greater than 50°C/s is high, yield strength as well as tensile strength is also increased and, thus, it may be difficult to satisfy a yield ratio of 0.85 or less.

[Mode for Invention]

[0067] Hereinafter, the present disclosure will be described in detail by explaining exemplary embodiments. However, the features of the present disclosure will be more clearly understood and should not be limited by the exemplary embodiments of the present disclosure. The scope of the present disclosure should be determined by the appended claims and their equivalents coming within the meaning of the appended claims are intended to be embraced therein.

[0068] A slab that satisfies a component system shown in Table 1 below was heated to 1160°C, was rough-rolled at 1000°C and, then, was hot-rolled and cooled to satisfy a manufacturing condition shown in Table 2 below to acquire steel. The yield strength, tensile strength, yield ratio, and refined structure of the steel were measured and shown in Table 3 below.

[0069] In addition, pole strength of (100) and (110) crystalline surfaces of the steel was measured to obtain a value of $PI_{max. (111)}/PI_{max. (100)}$ and the value was shown in Table 3 below.

[0070] The yield strength and the tensile strength were measured using a universal tensile tester.

[0071] A refined structure was obtained by mirror-like grinding the steel and, then, performing chemical corrosion and, then, was observed by an optical microscope.

[0072] Pole strength and entire structure strength were measured via an X-ray diffractometer and an electron back-scatter diffractometer.

[0073] A unit of content of each element is wt% in Table 1 below.

Table 1

Steel Type	C	Si	Mn	P	S	Al	Cr	Ni	Ti	Nb	B	N	Ca	Sn
Invention steel A	0.045	0.17	2.12	0.007	0.002	0.029	0.32	0.40	0.018	0.04	0.0016	0.0037	0.00 10	0.0008
Invention steel B	0.052	0.15	2.48	0.008	0.001	0.026	0.30	0.15	0.016	0.04	0.0015	0.0035	0.00 07	0.0042
Invention steel C	0.065	0.16	1.75	0.011	0.001	0.030	0.29	0.29	0.019	0.04	0.0014	0.0029	0.00 12	0.0021
Invention steel D	0.054	0.25	2.29	0.007	0.002	0.030	0.31	0.50	0.011	0.03	0.0013	0.0042	0.00 05	0.0034
Invention steel E	0.045	0.11	1.91	0.005	0.003	0.006	0.04	1.52	0.008	0.01	0.0001	0.0040	0.00 11	0.0004
Comparison Steel F	0.049	0.15	2.85	0.009	0.002	0.029	0.28	0.41	0.018	0.03	0.0015	0.0040	0.00 14	0.0003

Table 2

Steel type	Division	Hot final rolling		Cooling		Bs Temperature (°C)
		Temperature (C)	Reduction Ratio (%)	Cooling Speed (°C/s)	Termination Temperature (°C)	
Invention steel A	Invention Example 1	844	75	46.6	523	589
	Invention Example 2	860	70	41.1	537	
	Invention Example3	892	60	40.6	492	
Invent on steel E	Invention Example4	873	70	41.2	536	565
	Invention Example5	890	60	37.7	506	
	Invention Example6	901	60	26.2	441	
Invention steel C	Invention Example7	899	60	25.8	451	623
	Invention Example8	890	60	26.3	447	
	Invention Example9	859	70	41.4	528	
Invention steel D	Comparison Example1	852	75	51.4	534	568
	Comparison Example2	863	75	57.7	507	
	Comparison Example3	904	45	6.4	182	
Comparison Steel E	Comparison Example4	870	72	34.1	350	574
	Comparison Example5	871	66	24.1	356	
	Comparison Example6	869	52	20.2	357	
Comparison Steel F	Comparison Example7	864	78	48.5	505	526
	Comparison ExampleE	877	65	31.4	502	
	Comparison Example9	835	55	20.4	496	

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Table 3

Steel Type	Division	Central portion Refined structure			Yield strength (MPa)	Tensile Strength (MPa)	Yield Ratio	P _{lmax} .(111) /P _{lmax} . (100)
		BF	GB	M.A				
Invention Steel A	Invention Example 1	86	12	2	677	843	0.80	1.14
	Invention Example 2	89	10	1	703	872	0.81	1.25
	Invention Example 3	91	8	1	717	909	0.79	1.50
Invention Steel B	Invention Example 4	87	10	3	697	866	0.80	1.16
	Invention Example 5	92	6	2	736	898	0.82	1.64
	Invention Example 6	88	11	1	707	871	0.81	1.27
Invention Steel C	Invention Example 7	92	7	1	761	919	0.83	1.52
	Invention Example 8	93	7	0	786	926	0.85	1.71
	Invention Example 9	83	15	2	686	860	0.80	1.10
Invention Steel D	Comparison Example 1	97	3	0	797	931	0.86	1.98
	Comparison Example 2	98	2	0	893	981	0.91	1.96
	Comparison Example 3	71	24	5	613	780	0.79	0.87
Comparison Steel E	Comparison Example 4	AF: 72, B: 28			562	694	0.81	1.08
	Comparison Example 5	AF: 79, B: 21			530	643	0.82	1.05
	Comparison Example 6	AF: 74, B: 26			504	612	0.82	1.07
Comparison Steel F	Comparison Example 7	BF: 97 , GB: 3, MA: 0			876	984	0.89	1.97
	Comparison Example 8	BF: 72, GB: 24, MA: 4			725	841	0.86	0.85
	Comparison Example 9	BF: 66, GB: 31, MA: 3			660	776	0.85	0.82

[0074] In Table 3 above, BF is bainitic ferrite, GB is granular bainite, MA is martensite austenite constituent, AF is accicular ferrite, and B is bainite and their unit is area%.

[0075] It may be seen that Invention Examples 1 to 9 that satisfy the alloy composition and manufacturing condition according to the present disclosure are capable of ensuring a low yield ratio of 0.85 or less and tensile strength of 800 MPa or more.

[0076] On the other hand, Comparison Examples 1 to 3 satisfy the alloy composition according to the present disclosure but do not satisfy the manufacturing condition and, thus, it may be seen that a low yield ratio is not capable of being

ensured or tensile strength is degraded.

[0077] Comparison Examples 4, 7, and 8 satisfy the manufacturing condition according to the present disclosure but do not satisfy the alloy composition and, thus, it may be seen that a low yield ratio is not capable of being ensured.

[0078] While the present disclosure has been described referring to the exemplary embodiments of the present disclosure, those skilled in the art will appreciate that many modifications and changes can be made to the present disclosure without departing from the spirit and essential characteristics of the present disclosure.

Claims

1. Low-yield-ratio type, high-strength steel comprising:

0.02 to 0.11 wt% of carbon (C);
 0.1 to 0.5 wt% of silicon (Si);
 1.5 to 2.5 wt% of manganese (Mn);
 0.01 to 0.06 wt% of aluminum (Al);
 0.1 to 0.6 wt% of nickel (Ni);
 0.01 to 0.03 wt% of titanium (Ti);
 0.005 to 0.08 wt% of niobium (Nb);
 0.1 to 0.5 wt% of chromium (Cr);
 0.01 wt% or less of phosphorus (P);
 0.01 wt% or less of sulfur (S);
 5 to 30 wt ppm of boron (B);
 20 to 70 wt ppm of nitrogen (N);
 50 wt ppm or less of calcium (Ca) (excluding 0);
 5 to 50 wt ppm or less of tin (Sn);
 iron (Fe) as a remainder thereof; and
 other inevitable impurities.

2. The low-yield-ratio type, high-strength steel of claim 1, wherein the steel further includes one or more of 0.1 to 0.5 wt% of copper (Cu), 0.15 to 0.3 wt% of molybdenum (Mo), and 0.005 to 0.3 wt% of vanadium (V).

3. The low-yield-ratio type, high-strength steel of claim 1, wherein a refined structure of the steel includes bainitic ferrite and granular bainite in a primary phase and includes M-A in a secondary phase.

4. The low-yield-ratio type, high-strength steel of claim 3, wherein the bainitic ferrite has an area fraction of 80 to 95%, the granular bainite has an area fraction of 5 to 20%, and the M-A has an area fraction of 3% or less (including 0%).

5. The low-yield-ratio type, high-strength steel of claim 1, wherein $PI_{max. (111)} / PI_{max. (100)}$ as a ratio of pole intensity ($PI_{max.}$) of (100) and (111) crystalline surfaces of the steel is 1.0 or more or 1.8 or less (where the $PI_{max. (111)}$ is pole intensity of the (111) crystalline surface and the $PI_{max. (100)}$ is pole intensity of the (100) crystalline surface).

6. The low-yield-ratio type, high-strength steel of claim 1, wherein the steel has a yield ratio of 0.85 or less and has tensile strength of 800 MPa or more.

7. The low-yield-ratio type, high-strength steel of claim 1, wherein the steel has a thickness of 60 mm or less.

8. A method of manufacturing low-yield-ratio type, high-strength steel, the method comprising:

heating a slab including 0.02 to 0.11 wt% of carbon (C), 0.1 to 0.5 wt% of silicon (Si), 1.5 to 2.5 wt% of manganese (Mn), 0.01 to 0.06 wt% of aluminum (Al), 0.1 to 0.6 wt% of nickel (Ni), 0.01 to 0.03 wt% of titanium (Ti), 0.005 to 0.08 wt% of niobium (Nb), 0.1 to 0.5 wt% of chromium (Cr), 0.01 wt% or less of phosphorus (P), 0.01 wt% or less of sulfur (S), 5 to 30 wt ppm of boron (B), 20 to 70 wt ppm of nitrogen (N), 50 wt ppm or less of calcium (Ca) (excluding 0), 5 to 50 wt ppm or less of tin (Sn), iron (Fe) as a remainder thereof, and other inevitable impurities, at 1050 to 1250°C ;
 rough-rolling the heated slab at 950 to 1050°C to acquire a bar;
 hot-rolling the bar at final rolling temperature of 700 to 950°C to acquire hot rolled steel; and
 cooling the hot rolled steel at cooling speed of 25 to 50°C/s up to cooling termination temperature of Bs or less.

9. The method of claim 8, wherein the slab further includes one or more of 0.1 to 0.5 wt% of copper (Cu), 0.15 to 0.3 wt% of molybdenum (Mo), and 0.005 to 0.3 wt% of vanadium (V).
10. The method of claim 8, wherein the hot-rolling is performed at a reduction ratio of 50 to 80%.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/KR2016/014135

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/58(2006.01)i, C22C 38/50(2006.01)i, C22C 38/48(2006.01)i, C22C 38/06(2006.01)i, C22C 38/02(2006.01)i, C22C 38/00(2006.01)i, C22C 38/42(2006.01)i, C22C 38/44(2006.01)i, C22C 38/46(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 38/58; C21D 8/02; C22C 38/00; C22C 38/14; C21D 8/00; C22C 38/04; B21B 3/00; C22C 38/50; C22C 38/48; C22C 38/06; C22C 38/02; C22C 38/42; C22C 38/44; C22C 38/46

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, high strength, steel plate, bainitic ferrite, hot rolling

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	KR 10-2015-0002958 A (HYUNDAI STEEL COMPANY) 08 January 2015 See paragraphs [0001]-[0085]; and figure 1.	1-2,6-7
Y		3-5,8-10
Y	KR 10-2015-0074968 A (POSCO) 02 July 2015 See paragraphs [0001]-[0015].	3-5,8-10
A	KR 10-2009-0052950 A (POSCO) 27 May 2009 See paragraphs [0001]-[0053]; and figure 2.	1-10
A	KR 10-2014-0118316 A (HYUNDAI STEEL COMPANY) 08 October 2014 See paragraphs [0008]-[0089]; and figure 1.	1-10
A	JP 5679091 B1 (JFE STEEL CORP.) 16 January 2015 See paragraphs [0001]-[0088]; and figure 1.	1-10

☐ 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

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“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

07 MARCH 2017 (07.03.2017)

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INTERNATIONAL SEARCH REPORT Information on patent family members

International application No.

PCT/KR2016/014135

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REFERENCES CITED IN THE DESCRIPTION

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