(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 071 261 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
12.10.2022 Bulletin 2022/41

(21) Application number: **20896407.2**

(22) Date of filing: **27.11.2020**

(51) International Patent Classification (IPC):
C22C 38/04 *(2006.01)* ***C22C 38/08*** *(2006.01)*
C22C 38/14 *(2006.01)* ***C22C 38/16*** *(2006.01)*
C21D 8/02 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
Y02E 10/72; Y02E 10/727; Y02P 70/50

(86) International application number:
PCT/KR2020/017125

(87) International publication number:
WO 2021/112503 (10.06.2021 Gazette 2021/23)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **06.12.2019 KR 20190162011**

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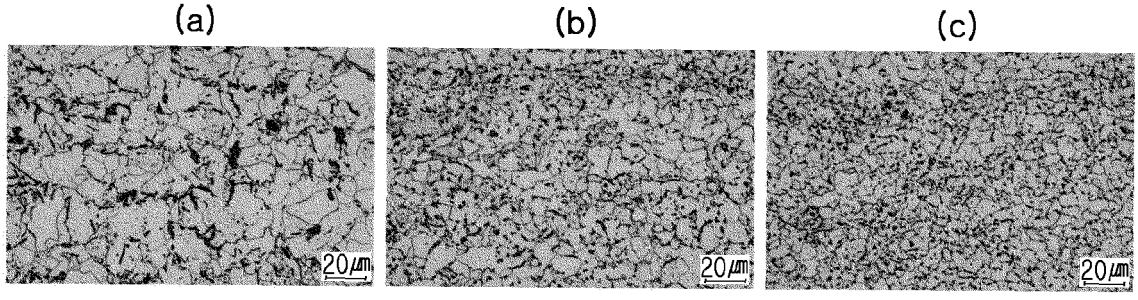
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(54) NORMALIZING HEAT TREATED STEEL SHEET HAVING GOOD LOW IMPACT TOUGHNESS AND METHOD FOR MANUFACTURING SAME

(57) A normalizing heat treated steel sheet having good low impact toughness and a method for manufacturing the same are provided. The normalizing heat treated steel sheet of the present invention contains, by weight %, C: 0.04 to 0.1%, Si: 0.05 to 0.5%, Mn: 1.0 to 2.0%, Sol.Al: 0.015 to 0.04%, Nb: 0.003 to 0.03%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, Ni: 0.05 to 0.8%, N: 0.002 to 0.008%, P: 0.01% or less (excluding 0%), S: 0.003% or less, and the balance of Fe and unavoidable impurities, and has a steel microstructure consisting of 70 to 90 area% of polygonal ferrite having a grain size of 20 μm or less, and 10 to 30 area% of spheroidized pearlite.

[Fig. 2]



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Description

Technical Field

[0001] The present disclosure relates to manufacturing a normalizing heat-treated steel sheet having good low-temperature impact toughness, and more particularly, to a normalizing heat-treated steel sheet having good central impact properties of an ultra-thick steel sheet, which can be applied to an industrial steel material for structural use in various fields such as marine and wind power building structures, thereby securing stability and increasing a lifespan of the structure, and a manufacturing method thereof.

Background Art

[0002] In recent years, as energy resources on land or offshore are depleted, resource mining regions are gradually moving to deep sea regions or cold regions, and accordingly, due to enlargement and integration, and the like, of drilling, mining, and storage facilities, the resource mining regions are becoming increasingly complex. The steel material used therefor is required to have excellent low-temperature toughness in order to secure stability of the structure, and in particular, it is necessary to minimize a decrease in toughness due to cold working during a process of manufacturing the structure.

[0003] The development of marine energy and resources is expanding to the deep sea, cold regions, and polar regions, and the construction of floating offshore structures such as SPAR, TLP, and FPSO is actively underway. Such offshore structures must be absolutely safe in relation to the protection of the marine environment, and thus, damage to the offshore structures is almost unacceptable.

[0004] In addition, since the 2000s, attention has been focused on new and renewable energy for reducing environmental issues and greenhouse gas emissions. Renewable energy is a term combining new energy (hydrogen, fuel cells, and the like) and renewable energy (solar heat, wind power, bio, and the like), and thereamong, wind power generation is in the spotlight as a next-generation energy source as an eco-friendly power generation method generating no waste and no pollution.

[0005] Among wind power generation, onshore wind power installed on land has a rapid growth in recent years, mainly in Europe, due to limitations in noise, an optimal wind formation space, and the like. Although such offshore wind power was activated later than onshore wind power, the relative superiority of offshore wind power over onshore wind power is increasingly emerging as a technological level develops due to various advantages such as a strong wind speed, low concerns about noise generation, and an ability to secure a large area.

[0006] The structure of such offshore wind power is divided into a monopile portion that is embedded into a seafloor surface, a transition piece portion connecting the monopile and tower portion, and a tower portion supporting facilities generating power.

[0007] Thereamong, the monopile and transition piece portions support offshore wind power. Most thereof require cylindrical curved surface processing, so thick steel plates that can guarantee extremely thick and low-temperature toughness are used. In more detail, a steel material that has a maximum thickness of 120 mm and a -50°C impact toughness and yield strength satisfying 350 MPa is required.

[0008] In this respect, steel materials are being strengthened and thickened, but in terms of safety, it is very important to secure the low-temperature toughness of ultra-thick materials. However, in general, there are attempts to control a grain size by adjusting a heat treatment temperature to improve the impact properties in heat-treated steel materials applied to marine, wind power structures, and the like, and performing a multi-step heat treatment, but basically, the heat-treated steel sheet securing strength by high carbon content has a limitation in securing central portion impact toughness.

[Prior art Document]

[Patent Document]

[0009] (Patent Document 1) Korean Patent Publication No. KR2016-0063168

Summary of Invention

Technical Problem

[0010] The present disclosure relates to a steel sheet satisfying strength of 350 MPa or more for a thick steel sheet subjected to normalizing heat treatment and at the same time having excellent central portion impact toughness. An

aspect of the present disclosure is to provide a normalizing heat-treated steel sheet having excellent low impact toughness and a method for manufacturing the same. In the normalizing heat-treated steel sheet, by realizing a microstructure comprising ferrite having a final grain size of 20 μm or less and spheroidized pearlite by heat treatment through controlling a steel composition and a manufacturing method thereof, impact inferiority of an existing heat-treated steel sheet may be overcome and strength of a base material and central portion toughness at 60 to -40°C may be secured, so that it can be used as a steel material for offshore structures and wind power structures.

[0011] The subject of the present invention is not limited to the above. The subject of the present invention will be understood from the overall content of the present specification, and those of ordinary skill in the art to which the present invention pertains will have no difficulty in understanding the additional subject of the present invention.

Solution to Problem

According to an aspect of the present disclosure,

[0012] a normalizing heat-treated steel sheet having good low-temperature impact toughness includes, by weight %, C: 0.04 to 0.1%, Si: 0.05 to 0.5%, Mn: 1.0 to 2.0%, Sol. Al: 0.015 to 0.04%, Nb: 0.003 to 0.03%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, Ni: 0.05 to 0.8%, N: 0.002 to 0.008%, P: 0.01% or less (excluding 0%), S: 0.003% or less, and a balance of Fe and unavoidable impurities and has a steel microstructure comprising 70 to 90 area% of polygonal ferrite having a grain size of 20 μm or less, and 10 to 30 area% of spheroidized pearlite.

[0013] The heat-treated steel sheet has yield strength of 350 MPa or more, and may exhibit an impact absorption energy value of 150 J or more at -60°C.

[0014] According to another aspect of the present disclosure,

a method for manufacturing a normalizing heat-treated steel sheet having good low-temperature impact toughness includes processes of: reheating a steel slab including, by weight %, C: 0.04 to 0.1%, Si: 0.05 to 0.5%, Mn: 1.0 to 2.0%, Sol. Al: 0.015 to 0.04%, Nb: 0.003 to 0.03%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, Ni: 0.05 to 0.8%, N: 0.002 to 0.008%, P: 0.01% or less (excluding 0%), S: 0.003% or less, and a balance of Fe and unavoidable impurities at a temperature of 1020~1150°C;

manufacturing a hot-rolled steel sheet by finish hot rolling the reheated steel slab in a non-recrystallization temperature region at Ar3 temperature or higher;

air-cooling or water-cooling the hot-rolled steel sheet; and

normalizing in which the cooled hot-rolled steel sheet is heated to a temperature range of 850 to 960°C, and then maintained for [1.3 t+(10 to 30)] minutes (where t is a value measured in mm of a thickness of the hot-rolled steel sheet).

[0015] The finish rolling temperature is preferably in a range of 760 to 810°C.

[0016] When the hot-rolled steel sheet is water-cooled, the steel sheet may be cooled to a temperature range of 500 to 300°C at a cooling rate of 2 to 30°C/s.

[0017] The normalizing steel sheet may have a steel microstructure including 70 to 90 area % of polygonal ferrite having a grain size of 20 μm or less and 10 to 30 area % of spheroidized pearlite.

Advantageous Effects of Invention

[0018] In the present disclosure having the configuration as described above, a normalizing heat-treated steel having low-temperature toughness properties having a microstructure comprising 70 to 90 area% of polygonal ferrite having a grain size of 20 μm or less and 10 to 30 area% of spheroidized pearlite through the control of steel components and manufacturing conditions may be provided. An ultra-thick heat-treated steel sheet provided in this manner may have yield strength of 350Mpa or more, and may exhibit an excellent central portion impact absorption energy value of 150 J or more at -40 and -60°C.

[0019] In addition, these steel materials may be applied as structural steel materials for offshore structures and wind power structures, and can be prepared for the risk of destruction of steel due to low water temperature, and can also be applied to shipbuilding and general structural steels requiring low-temperature toughness.

Brief Description of Drawings

[0020]

FIG. 1 is a photograph illustrating a microstructure of steel before a normalizing heat treatment, FIG 1(a) illustrates

a general rolled material, FIG. 1(b) illustrates a non-recrystallization region rolled + air cooled material of the present disclosure, and FIG. 1(c) illustrates a non-recrystallization region rolled + water cooled material.

FIG. 2 illustrates a final microstructure of steel after a normalizing heat treatment, FIG 2(a) illustrates a general rolled + normalized material, FIG. 2(b) illustrates a non-recrystallization region rolled + air cooled + normalized material of the present disclosure, and FIG. 2(c) illustrates a non-recrystallization region rolled + water cooled + normalized material of the present disclosure.

Best Mode for Invention

[0021] Hereinafter, the present disclosure will be described.

[0022] The present disclosure relates to a heat-treated steel material having excellent central portion impact properties of an ultra-thick steel sheet, and the heat-treated steel material of the present disclosure may be rolled at a non-recrystallization region temperature to finely control an initial grain size before normalizing heat treatment. In addition, it is possible to form a finer final grain size of 20 μm or less after normalizing heat treatment, so that it can be applied to various structural industrial steel materials such as marine and wind power building structures, thereby securing the stability of the structures and increasing a lifespan thereof.

[0023] In order to implement the microstructure in the present disclosure, it is required to start rolling at about 870 to 830° C instead of conventional high-temperature rolling, and to perform air cooling or water cooling after rolling and to carry out heat treatment. A heat-treated ultra-thick steel sheet manufactured in this manner makes it possible to obtain a low-carbon normalizing heat-treated steel having increased strength due to a fine final microstructure, so that the heat-treated ultra-thick steel sheet may overcome inferiority of the central portion impact toughness, which is a disadvantage of an existing heat-treated steel having a high carbon content, and may have an excellent absorption energy value having central portion impact toughness of 150J or more even at -60°C.

[0024] Specifically, the conventional normalizing heat treatment steel is a TMCP steel material manufactured by control rolling + cooling to secure strength, and had a tendency to be inferior in impact toughness even after heat treatment because of a high carbon content thereof. In addition, when the heat treatment temperature is too high or too long, a case in which the strength may decrease compared to the steel sheet in a rolled state before heat treatment due to grain growth occurs.

[0025] In order to overcome this, the present disclosure has a feature of providing a normalizing heat-treated steel material having excellent strength and center portion impact toughness by performing non-recrystallization region rolling, and water cooling or air cooling after rolling to secure grain refinement of the structure as well as implementing the final grain refinement after normalizing.

[0026] A normalizing heat-treated steel sheet having good low-temperature impact toughness according to the present disclosure includes, by weight %, C: 0.04 to 0.1%, Si: 0.05 to 0.5%, Mn: 1.0 to 2.0%, Sol. Al: 0.015 to 0.04%, Nb: 0.003 to 0.03%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, Ni: 0.05 to 0.8%, N: 0.002 to 0.008%, P: 0.01% or less (excluding 0%), S: 0.003% or less, and a balance of Fe and unavoidable impurities and has a steel microstructure comprising 70 to 90 area% of polygonal ferrite having a grain size of 20 μm or less, and 10 to 30 area% of spheroidized pearlite.

[0027] Hereinafter, the steel composition component of the present disclosure and the reason for limiting its content will be described. Meanwhile, "%" as used herein means "%" by weight, unless otherwise specified.

C: 0.04 to 0.1%

[0028] In the present disclosure, C is an element for securing tensile strength by causing solid solution strengthening and being present as carbonitride by Nb, or the like. However, if a content of C is less than 0.04%, a decrease in tensile strength may occur due to a decrease in solid solution strengthening by C. On the other hand, when 0.1% or more of C is added, pearlite is generated, which may deteriorate impact and fatigue properties at a low temperature, and furthermore, as solid solution C increases, impact properties may deteriorate. Therefore, in the present disclosure, a C content is preferably limited in a range of 0.04 to 0.1%. More preferably, the C content is limited to 0.06 to 0.09%.

Si: 0.05 to 0.5%

[0029] Si assists Al to deoxidize molten steel and is a necessary element to secure yield and tensile strength. However, if a content of Al is less than 0.05%, the above effects cannot be obtained and a treatment time in a steelmaking process is greatly increased. On the other hand, when an amount of Si added exceeds 0.5%, diffusion of C is prevented and MA formation is promoted, which may impair impact and fatigue properties at a low temperature. Therefore, in the present disclosure, a Si content is preferably limited in a range of 0.05 to 0.5%, and more preferably, and more preferably, the Si content is limited to 0.02 to 0.05% in order to ensure stable strength.

Mn: 1.0 to 2.0%

[0030] Mn is added in an amount of 1.0% or more because Mn has a great strength increase effect by solid solution strengthening. However, when Mn is excessively added, deterioration of toughness may occur due to formation of MnS inclusions and segregation in a central portion, so that an upper limit thereof is limited to 2.0%. More preferably, the Mn content is limited to 1.5 to 2.0% in order to ensure stable strength.

P: 0.01% or less

[0031] Since P is an element that causes grain boundary segregation and may cause the steel to embrittlement, an upper limit of P is required to be limited to 0.01%.

S: 0.003% or less

[0032] S mainly combines with Mn to form MnS inclusions, which are factors inhibiting low-temperature toughness. Therefore, in order to secure low-temperature toughness and low-temperature fatigue characteristics, it is necessary to limit S to a range of 0.003% or less.

Al: 0.015 to 0.04%

[0033] In the present disclosure, Al needs to be added in an amount of 0.015% or more as a major deoxidizing agent for steel. In addition, since it is an element necessary to fix an N component during strain aging, at least 0.015% should be added. However, when Al is added in excess of 0.04%, it may cause deterioration of low-temperature toughness due to an increase in fraction and size of Al_2O_3 inclusions. In addition, it is preferable to limit the Al content to 0.015 to 0.04%, more preferably, to limit the Al content to 0.02 to 0.03%, because similarly to Si, it promotes generation of an MA phase of a base material and a weld heat-affected zone to degrade the low-temperature toughness and low-temperature fatigue properties.

Ti: 0.005 to 0.02%

[0034] Ti is combined with N causing strain aging to form Ti nitride (TiN) to reduce a solid solution N content, so Ti must be added at least 0.005%. These precipitates suppress coarsening of a microstructure, thereby contributing to the refinement thereof and improving the toughness. However, if a content of Ti exceeds 0.02%, it may cause fracture by coarsening of precipitates, and solid solution Ti that cannot be combined with N remains to form Ti carbide (TiC), which reduces the toughness of the base metal and weld zones, so an upper limit thereof is set to 0.02%. More preferably, the Ti content is limited to 0.01 to 0.015%.

Cu: 0.35% or less

[0035] Cu is a component that does not significantly reduce impact properties, and improves the strength of steel by solid solution and precipitation. However, when excessively added, since surface cracks of a steel sheet due to Cu thermal shocks may occur, it is preferable to limit an upper limit thereof to 0.35%, and more preferably, the upper limit thereof is limited to 0.25% or less.

Ni: 0.05 to 0.8%

[0036] Ni is an element that can improve strength and toughness at the same time, although the enhancement of strength is not large as a content of Ni increases. In order for the effect to appear, Ni must be added at least 0.05%. However, since it is an expensive element, addition of in excess of 0.8% is not preferable in terms of economic efficiency. More preferably, the N content is limited to 0.2 to 0.7%.

Nb: 0.003 to 0.03%

[0037] Nb is an element that suppresses recrystallization during rolling or cooling by solid solution or precipitating carbonitride to make a structure finer and increase strength, and a content of Nb needs to be 0.003% or more. However, it is preferable to limit the content of Nb to 0.003 to 0.03% because C concentration occurs due to C affinity, which promotes formation of MA phase and reduces toughness and fracture properties at a low temperature. More preferably, the Nb content is limited to 0.01 to 0.025%.

N: 0.002 to 0.008%

[0038] N is a major element causing strain aging together with C, and it is desirable to keep it low. Al, Ti, Nb, B, and the like should be appropriately included in order to reduce deterioration resulted from the strain aging impact due to N. However, if a N content is too high, it becomes difficult to suppress the strain aging effect. Therefore, the N content is limited to 0.008% or less. On the other hand, if the N content is too small, an element added thereto to suppress deterioration of strain aging impact causes solid solution strengthening in a solid solution state or forms other precipitates to reduce the toughness of the base material and welded portion, so a lower limit of the N content is limited to 0.002%. More preferably, the N content is limited to 0.003 to 0.006%.

Ca: 0.0002 to 0.0050%

[0039] When Ca is added to molten steel during steelmaking after Al deoxidation, Ca binds with S, which is mainly present as MnS, and suppresses MnS formation and at the same time forms spherical CaS to suppress cracks in a central portion of steel materials. Therefore, in the present disclosure, Ca must be added in an amount of 0.0002% or more in order to sufficiently form the added S into CaS. However, if the added amount is excessive, excess Ca is combined with O to generate coarse oxidative inclusions, which are elongated and fractured in subsequent rolling, acting as a crack initiation point at a low temperature. Therefore, an upper limit thereof is limited to 0.0050%.

[0040] In the present disclosure, as needed, 0.05% or less of Mo or 0.05% or less of Cr may be included.

[0041] A remainder of the present disclosure may be iron (Fe). However, in a general manufacturing process, inevitable impurities may be inevitably added from raw materials or an ambient environment, and thus, impurities may not be excluded. A person skilled in the art of a general manufacturing process may be aware of the impurities, and thus, the descriptions of the impurities may not be provided in the present disclosure. The content of other components contained as impurities is acceptable.

[0042] Meanwhile, a steel material of the present disclosure is mainly comprising polygonal ferrite and spheroidized pearlite.

[0043] In the steel material of the present disclosure, it is necessary to control the ferrite grain size to 20 μm or less in order to realize low-temperature impact toughness at -40°C to -60°C while securing strength in an ultra-thick normalizing heat-treated steel sheet having yield strength of 350 MPa or more.

[0044] More specifically, the steel material of the present disclosure has a steel microstructure including polygonal ferrite having a grain size of 20 μm or less: 70 to 90 area% and spherical pearlite: 10 to 30 area%. If a polygonal ferrite fraction is less than 70 area%, a decrease in toughness and ductility may occur, and if the polygonal ferrite fraction exceeds 90 area%, there may be a problem in securing yield strength and tensile strength.

[0045] Meanwhile, in general, it is impossible to secure polygonal ferrite having a grain size of 20 μm or less by general normalizing heat treatment.

[0046] Next, a manufacturing method of a normalizing heat treatment steel sheet having excellent low-temperature impact toughness of the present disclosure will be described in detail.

[0047] A method for manufacturing a normalizing heat-treated steel sheet of the present disclosure includes processes of: reheating a steel slab having the above composition at a temperature of 1020~1150°C; manufacturing a hot-rolled steel sheet by finishing hot rolling the reheated steel slab in a non-recrystallization temperature region of Ar3 temperature or higher; air-cooling or water-cooling the hot-rolled steel sheet to a temperature range of 500 to 300°C; and normalizing in which the cooled hot-rolled steel sheet is heated to a temperature range of 850 to 960°C, and then maintained for [1.3 t+(10 to 30)] minutes (where, t is a value measured in mm of the thickness of the hot-rolled steel sheet).

[0048] That is, the manufacturing process of the steel material of the present disclosure includes processes of slab reheating; rolling the slab in a non-recrystallization region; cooling, and the contents of each process are as follows.

[0049] First, in the present disclosure, a steel slab having the above composition is reheated to 1020 to 1150°C.

[0050] The reheating temperature is preferably 1020 to 1150°C. If the heating temperature is too high (exceeding 1150°C), the grains of austenite become coarse, so that toughness can be degraded. If the heating temperature is too low (less than 1050°C), there may be a case in which Ti, Nb, or the like may not be sufficiently dissolved, which may result in a decrease in strength.

[0051] Next, in the present disclosure, a hot-rolled steel sheet is manufactured by finish hot rolling the reheated steel slab in a non-recrystallization temperature region at Ar3 or higher.

[0052] In the present disclosure, the recrystallization region rolling during hot rolling is performed only in a role of adjusting a size of a width of a product. That is, in the present disclosure, grain refinement can be achieved by minimizing recrystallization rolling and maximizing non-recrystallization rolling. If a slab width is larger than a plate width after rolling, it is preferable to omit the recrystallization region rolling.

[0053] In the present disclosure, the non-recrystallization region rolling should start at a recrystallization temperature, approximately 850°C, or lower, and should be completed at an Ar3 temperature or higher at about 750°C or higher, and

have a rolling amount of 90 to 100% with respect to a target thickness.

[0054] If the finish rolling temperature is higher than a non-recrystallization temperature, the grain size growth occurs before air cooling or water cooling, which makes it difficult to secure strength and toughness. If the finish rolling temperature is lower than an Ar3 temperature, two-phase region rolling occurs and the structure becomes anisotropic and band-shaped, which may cause a significant decrease in impact toughness.

[0055] In the present disclosure, the finish rolling temperature is preferably in a range of 760 to 810°C.

[0056] In the present disclosure, the hot-rolled steel sheet is air-cooled or water-cooled.

[0057] In the present disclosure, the finish hot-rolled steel sheet realizes strength and microstructure through water cooling or air cooling. In the case of water cooling, although there is a difference depending on the thickness, cooling is preferably performed at a cooling rate of 2-30°C/sec to 500-300°C.

[0058] Among the steel materials manufactured in this manner, a microstructure of the water-cooled material includes ferrite having a size of 20 μm or less, an average of about 13 μm, and a fraction of 80 area% or more, and MA and cementite of 20 area% or less.

[0059] Meanwhile, a microstructure of the steel material manufactured by air cooling includes ferrite having a size of 20 μm or less, an average of about 16 μm, and a fraction of 75 to 90 area% and pearlite having about 10 to 25 area%.

[0060] Subsequently, in the present disclosure, normalizing heat treatment in which the cooled hot-rolled steel sheet is heated to a temperature range of 850 to 960°C, and then maintained for [1.3 t + (10 to 30)] minutes is performed [where t is a value measured in mm of the thickness of the hot-rolled steel sheet].

[0061] When a normalizing temperature is less than 850°C or a holding time is less than (1.3t+10) minutes, it is difficult to re-dissolve cementite in pearlite, so dissolved C decreases, making it difficult to secure strength and finally, the remaining cementite coarsely remains. On the other hand, when the normalizing temperature exceeds 960°C or the maintaining time exceeds (1.3t+30) minutes, all carbides existing in ferrite grains move to grain boundaries or coarsen the carbides so that a spherical pearlite distribution cannot be formed. As a cooling time during air cooling after heat treatment increases, the ferrite grain size increases, which may lead to a decrease in strength and toughness.

[0062] The ultra-thick normalizing heat treatment steel of the present disclosure prepared in manner way may exhibit excellent impact toughness, including 70 to 90 area% of ferrite having an average particle diameter of 20 μm or less and 10 to 30 area% of spheroidized pearlite in the final microstructure.

Mode for Invention

[0063] Hereinafter, the present disclosure will be described in more detail through examples.

(Example)

[0064] After preparing molten steel having a component composition illustrated in Table 1 below, a steel slab was manufactured using continuous casting. The steel slab thus prepared was subjected to hot rolling, cooling, and normalizing treatment under manufacturing conditions shown in Table 2 below to manufacture a steel sheet. Meanwhile, in Table 1 below, Inventive steels A to C are steel sheets satisfying a component range specified in the present disclosure, and Comparative steels D to E are steel sheets not satisfying the component range specified in the present disclosure. In Table 1, a unit of each element content is weight %.

[0065] Mechanical properties of each of the prepared steel sheets were measured and shown in Table 3 below. Here, each structure fraction and grain size were obtained through image analysis using an optical microscopy. In addition, tensile strength, yield strength, and elongation were obtained through a tensile test according to an ASTM tensile standard by processing a round specimen by collecting the same in a direction perpendicular to rolling, and an impact value was also obtained from a 1/4 thickness of the steel sheet, in a direction perpendicular to the rolling, and the specimen was processed and then an impact test was performed at each temperature (-40, -60°C).

[0066]

[Table 1]

Classification	Steel type	C	Si	Mn	P	S	Al	Cu	Ni	Ti	Nb	N
Inventive Steel	A	0.078	0.203	1.67	0.01	<0.002	0.023	0.259	0.63	0.012	0.022	0.0035

(continued)

Classification	Steel type	C	Si	Mn	P	S	Al	Cu	Ni	Ti	Nb	N
Inventive Steel	B	0.079	0.205	1.66	0.01	<0.002	0.028	0.262	0.61	0.013	0.026	0.0039
Inventive Steel	C	0.065	0.245	1.81	0.03	<0.002	0.027	0.253	0.012	0.021	0.253	0.0034
Comparative Steel	D	0.154	0.253	1.72	0.01	<0.002	0.019	0.244	0.013	0.024	0.244	0.0040
Comparative Steel	E	0.035	0.192	1.68	0.02	<0.002	0.024	0.271	0.014	0.019	0.271	0.0038

[Table 2]

Classification	Test No.	Steel type	Reheating temperature (°C)	Finish rolling start temperature (°C)	Finish rolling end temperature (°C)	Cooling end temperature (°C)	Cooling rate (°C/s)	Normalizing temperature (°C)	Normalizing time (min.)
Inventive example 1	1	A	1149	815	784	341	5.6	890	93
Inventive example 2	2	B	1154	825	794	334	6.2	890	91
Inventive example 3	3	C	1146	811	793	-	-	890	90
Comparative example 1	4	A	1152	966	934	365	8.7.	890	90
Comparative example 2	5	B	1137	987	952	-	-	890	90
Comparative example 3	6	C	1141	803	781	381	8.9	890	398
Comparative example 4	7	D	1132	810	782	373	6.6	890	89
Comparative example 5	8	E	1138	807	804	364	7.2	890	92

[0067]

[Table 3]

Clasifi cation	Tes t No.	Ste el typ e	Ferrit e size	Ferrit e fracti on	Pearlit e fractio n	Yield stren gth	Tensile streng th	Elonga tion	Impact absorpti on energy (-40°C)	Impact absorptio n energy (-60°C)
Inventi ve example 1	1	A	14.5	88	12	379	515	35	246	189
Inventi ve example 2	2	B	13.8	84	16	390	517	38	266	179
Inventi ve example 3	3	C	15.2	81	19	374	513	35	275	201
Compara tive example 1	4	A	31.5	78	22	341	490	40	56	23
Compara tive example 2	5	B	28.2	80	20	338	481	41	71	18
Compara tive example 3	6	C	30.3	71	29	340	484	40	54	21
Compara tive example 4	7	D	16.2	65	35	395	521	33	45	11
Comparative example 5	8	E	15.8	92	8	325	468	41	286	184

[0068] As illustrated in Tables 1 to 3, it can be seen that Inventive examples 1 to 3 satisfying all of the alloy compositions and manufacturing conditions presented in the present disclosure can secure yield strength of 350 MPa or more, and impact toughness of 150J or more at -40°C, -60°C, which is excellent.

[0069] In contrast thereto, Comparative Examples 1 to 3 are cases in which the alloy composition presented in the present disclosure is satisfied, but the manufacturing conditions are not satisfied, which can be seen that at least one inferiority in mechanical properties occurred. Specifically, Comparative Examples 1 and 2 show a technique using general rolling, Comparative Example 1 is a case in which rolling at a high temperature and cooling is performed, and Comparative Example 2 is a case in which rolling is performed at a high temperature and then air-cooled, which can be seen that strength and toughness are inferior since both grain growth occurred. Comparative Example 3 is a case in which normalizing heat treatment was performed for a long time, and illustrated a decrease in strength and toughness due to ferrite growth.

[0070] In addition, it can be seen that Comparative Example 4 is a case in which a C content is exceeded in the alloy composition presented in the present disclosure so that impact toughness is inferior, and Comparative Example 5 is a case in which the C content is insufficient so that yield strength is not satisfied.

[0071] Meanwhile, FIG. 1 illustrates a photograph illustrating a steel microstructure before normalizing heat treatment, FIG. 1(a) illustrates a steel material of Comparative Example 2 subjected to general rolling, FIG. 1(b) is a steel material of Inventive example 3 subjected to non-recrystallization region rolling + air cooling of the present disclosure, and FIG. 1(c) illustrates a steel material of Inventive example 2 in which non-recrystallization region rolling + water cooling of the present disclosure was performed.

[0072] FIG. 2 is a photograph illustrating a final microstructure of steel after normalizing heat treatment, FIG. 2(a) illustrates a steel material of Comparative Example 2 subjected to general rolling + normalizing, FIG. 2(b) is a steel material of Inventive example 3 subjected to non-recrystallization region rolling + air cooling + normalizing of the present disclosure, and FIG. 2(c) illustrates a steel material of Inventive Example 2 in which non-recrystallization region rolling + water cooling+ normalizing of the present disclosure was performed.

[0073] Hereinafter, the present disclosure will be described in more detail through examples. However, it should be noted that the following examples are for illustrative purposes only and are not intended to limit the scope of the present disclosure. The scope of the present disclosure may be determined by matters described in the claims and matters able to be reasonably inferred therefrom.

[0074] While example 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 normalizing heat-treated steel sheet having good low-temperature impact toughness, comprising:
by weight %, C: 0.04 to 0.1%, Si: 0.05 to 0.5%, Mn: 1.0 to 2.0%, Sol. Al: 0.015 to 0.04%, Nb: 0.003 to 0.03%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, Ni: 0.05 to 0.8%, N: 0.002 to 0.008%, P: 0.01% or less (excluding 0%), S: 0.003% or less, and a balance of Fe and unavoidable impurities and has a steel microstructure comprising 70 to 90 area% of polygonal ferrite having a grain size of 20 μm or less, and 10 to 30 area% of spheroidized pearlite.

2. The normalizing heat-treated steel sheet having good low-temperature impact toughness of claim 1, wherein the heat-treated steel sheet has yield strength of 350MPa or more, and an impact absorption energy value of 150 J or more at -60°C.

3. A method for manufacturing a normalizing heat-treated steel sheet having good low-temperature impact toughness, comprising processes of:

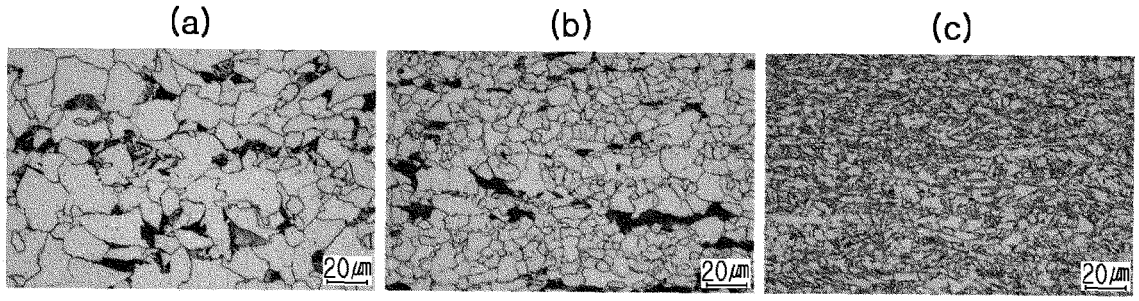
   reheating a steel slab including, by weight %, C: 0.04 to 0.1%, Si: 0.05 to 0.5%, Mn: 1.0 to 2.0%, Sol. Al: 0.015 to 0.04%, Nb: 0.003 to 0.03%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, Ni: 0.05 to 0.8%, N: 0.002 to 0.008%, P: 0.01% or less (excluding 0%), S: 0.003% or less, and a balance of Fe and unavoidable impurities at a temperature of 1020 to 1150°C;
   manufacturing a hot-rolled steel sheet by finish hot rolling the reheated steel slab in a non-recrystallization temperature region at a Ar3 temperature or higher;
   air-cooling or water-cooling the hot-rolled steel sheet; and
   normalizing in which the cooled hot-rolled steel sheet is heated to a temperature range of 850 to 960°C, and then maintained for [1.3 t+(10 to 30)] minutes, where t is a value measured in mm of a thickness of the hot-rolled steel sheet.

4. The method for manufacturing a normalizing heat-treated steel sheet having good low-temperature impact toughness of claim 3, wherein the finish rolling temperature is in a range of 760 to 810°C.

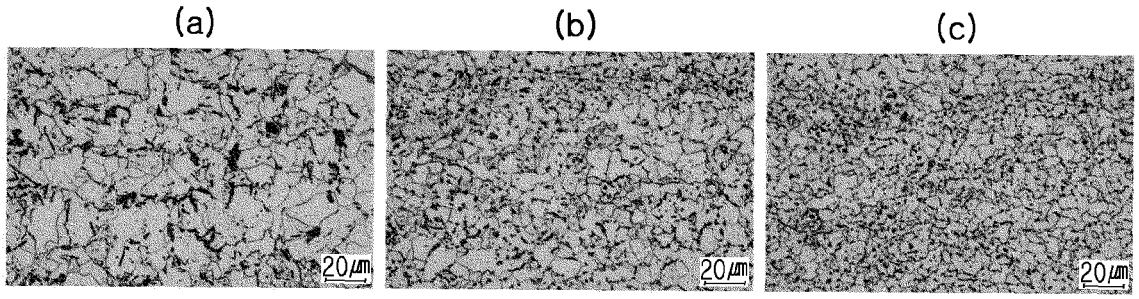
5. The method for manufacturing a normalizing heat-treated steel sheet having good low-temperature impact toughness of claim 3, wherein, when the hot-rolled steel sheet is water-cooled, it is cooled at a cooling rate of 2 to 30°C/s to a temperature range of 500 to 300°C.

6. The method for manufacturing a normalizing heat-treated steel sheet having good low-temperature impact toughness of claim 3, wherein the normalizing steel sheet has a steel microstructure comprising 70 to 90 area % of polygonal ferrite having a grain size of 20 μm or less, and 10 to 30 area % of spheroidized pearlite.

[Fig. 1]



[Fig. 2]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2020/017125

A. CLASSIFICATION OF SUBJECT MATTER

C22C 38/04(2006.01)i; **C22C 38/08**(2006.01)i; **C22C 38/14**(2006.01)i; **C22C 38/16**(2006.01)i; **C21D 8/02**(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(2006.01); C21D 8/00(2006.01); C21D 8/02(2006.01); C22C 38/00(2006.01); C22C 38/02(2006.01); C22C 38/06(2006.01); C22C 38/54(2006.01)

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: 강판(steel sheet), 저온충격인성(low temperature impact toughness), 노멀라이징(normalizing), 열처리(heat treat), 폴리고날 페라이트(polygonal ferrite), 펄라이트(pearlite)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2011-0060449 A (POSCO) 08 June 2011 (2011-06-08) See abstract and claims 1-7.	1-6
Y	KR 10-1949036 B1 (POSCO) 08 May 2019 (2019-05-08) See paragraphs [0085]-[0093] and [0104] and claims 1-9.	1-6
A	JP 07-278656 A (NIPPON STEEL CORP.) 24 October 1995 (1995-10-24) See abstract and claims 1-3.	1-6
A	JP 2009-228040 A (JFE STEEL CORP.) 08 October 2009 (2009-10-08) See abstract and claims 1-2.	1-6
A	US 2013-0092295 A1 (YOKOI et al.) 18 April 2013 (2013-04-18) See abstract and claims 1-2.	1-6

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

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"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
24 February 2021	**24 February 2021**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208** Facsimile No. **+82-42-481-8578**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2020/017125

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