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(54) **MANUFACTURING METHOD FOR A THICK STEEL PLATE HAVING EXCELLENT LOW-TEMPERATURE STRAIN AGING IMPACT PROPERTIES**

HERSTELLUNGSVERFAHREN FÜR DICKWANDIGE STAHLPLATTE MIT AUSGEZEICHNETEN NIEDRIGTEMPERATUR-RECKALTERUNGSIMPAKTEIGENSCHAFTEN

PROCÉDÉ DE FABRICATION D'UN TÔLE D'ACIER ÉPAISSE PRÉSENTANT D'EXCELLENTES PROPRIÉTÉS DE RÉSISTANCE AU VIEILLISSEMENT APRÈS CONTRAINTE À BASSE TEMPÉRATURE

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Description

[Technical Field]

[0001] The present invention relates to a thick steel plate having excellent low-temperature strain aging impact properties and a manufacturing method therefor and, more particularly, to a thick steel plate having excellent low-temperature strain aging impact properties that may be used as a material in ship building, marine structures and the like; and a manufacturing method therefor.

[Background Art]

[0002] Recently, mining areas have gradually moved to deep-sea areas or cold areas due to the depletion of land or offshore energy resources. Accordingly, boring, mining, and storage facilities are increasingly complicated due to the enlargement, integration, and the like of the facilities. Steel materials used therein are required to have excellent low-temperature toughness for securing stability of the structure and, in particular, are required to minimize the decrease in toughness due to a strain aging phenomenon by a cold working in a manufacturing process of the structure, or the like.

[0003] In general, the strain aging impact properties are evaluated by subjecting a steel plate to several percent of tensile strain, aging the steel plate at about 250°C for 1 hour, processing the aged steel plate to make an impact specimen, and then performing an impact test on the impact specimen. The more severe the strain aging phenomenon, the faster the toughness of the steel plate decreases, and the decrease in toughness may also increase. In this case, the lifespan of the site and the structure to which the steel plate is applied may be reduced and stability may be affected. Therefore, in recent years, a steel plate having high resistance to the strain aging phenomenon has been required for the purpose of increasing the lifespan of the steel plate subjected to strain to increase the stability of the structure.

[0004] Deterioration in impact toughness by the strain aging phenomenon may occur when yield strength is greater than breaking strength. In other words, the greater the difference between yield strength and breaking strength, the greater the amount of strain of the steel materials in ductility, and the absorbed impact energy may increase. Therefore, when cold deformation is performed to apply the steel materials to the structure, the yield strength of the steel materials may increase, to decrease the difference between the yield strength and the breaking strength, which is accompanied by a decrease in impact toughness.

[0005] The decrease in toughness due to the increase in yield strength may be caused by subjecting strain of the steel materials to fix interstitial elements in the steel materials such as C, N, and the like to the dislocation over time.

[0006] In order to prevent the decrease in toughness by cold deformation, conventionally, a method of significantly decreasing the amount of carbon (C) or nitrogen (N) dissolved in the steel materials for suppressing strength increase by an aging phenomenon after deformation, a method of adding an element such as nickel (Ni), or the like to lower stacking fault energy to facilitate the movement of dislocations, and the like have been applied. Alternatively, a method of performing stress relief heat treatment after cold deformation to decrease dislocation produced in the steel materials, thereby lowering the yield strength increased by work hardening, has been used, and, as an example thereof, Non-Patent Document 1 below is disclosed.

[0007] However, as structures and the like are continuously becoming larger and more complicated, the cold deformation amount required for the steel material is increased, and also the temperature of a use environment is lowered to the temperature level of arctic sea. Thus, it is difficult to effectively prevent a toughness decrease by strain aging of the steel material, with conventional methods.

[0008] US 2010/258219 A1 discloses a high-strength steel plate having acicular ferrite and bainite as a main microstructure and an austenite/martensite (M & A) as a second phase under the control of a cooling rate above the austenite transformation temperature. The high-strength steel plate comprises: carbon (C): 0.03 to 0.10 wt %, silicon (Si): 0.1 to 0.4 wt %, manganese (Mn): 1.8 wt % or less, nickel (Ni): 1.0 wt % or less, titanium (Ti): 0.005 to 0.03 wt %, niobium (Nb): 0.02 to 0.10 wt %, aluminum (Al): 0.01 to 0.05 wt %, calcium (Ca): 0.006 wt % or less, nitrogen (N): 0.001 to 0.006 wt %, phosphorus (P): 0.02 wt % or less, sulfur (S): 0.005 wt % or less, and the balance of iron (Fe) and other inevitable impurities. The method for manufacturing a high-strength steel plate may be useful to economically and effectively manufacture a high strength steel, which is able to secure excellent properties such as high strength and high toughness since the acicular ferrite and bainite may be effectively formed without adding expensive elements such as molybdenum (Mo).

[0009] EP 3128029 Al discloses steel material for highly deformable line pipes that has specified strain aging resistance and HIC resistance and has a specific chemical composition and a metallographic structure composed mainly of ferrite and bainite. The total area fraction of the ferrite and the bainite is 90% or more, and the difference in hardness between the ferrite and the bainite is 70 or more in terms of Vickers hardness. Both before strain aging treatment at a temperature of 300°C or lower and after the strain aging treatment, the steel material has a uniform elongation of 9% or more and a yield ratio of 90% or less.

(Non-Patent Document 1) The effect of processing variables on the mechanical properties and strain ageing of high-strength low-alloy V and VN steels (VK Heikkinen and JD Boyd, CANADIAN METALLURGICAL QUARTERLY Volume 15 Number 3 (1976), P. 219~)

(Patent Document 1) US 2010/258219 A1

(Patent Document 2) EP 3128029 A1

[Invention]

[Technical Problem]

[0010] An aspect of the present invention is to provide a method of manufacturing a thick steel plate having excellent low-temperature strain aging impact properties.

[Technical Solution]

[0011] The invention is as defined in the accompanying claim.

[Advantageous Effects]

[0012] A thick steel plate having excellent low-temperature strain aging impact properties and excellent yield strength may be provided as a result of practicing the method defined herein.

[Description of Drawings]

[0013]

FIG. 1 is a captured photograph of a microstructure of Inventive Example 1 manufactured according to a method embodiment of the invention.
FIG. 2 is a captured photograph a microstructure of Comparative Example 1 not according to the invention.

[Best Mode for Invention]

[0014] Hereinafter, the invention will be described in detail. First, the alloy composition of the invention will be described. The content of the alloy composition described below means by weight.

Carbon (C): 0.04-0.08%

[0015] In the invention, C is an element which is effective for a solid solution strengthening, and may be present as carbonitride by Nb, and the like, to secure tensile strength. In order to obtain the effect, the C content is 0.04% or more. When the C content is excessive, not only may formation of a martensite-austenite (MA) be promoted, but pearlite may also be generated to degrade impact and fatigue properties at low temperatures. In addition, since strain aging impact properties decrease as an amount of solid solution C increases, the C content is in the range of 0.04 to 0.08%.

Silicon (Si): 0.05-0.4%

[0016] Si may be an element necessary for assisting Al to deoxidize molten steel, and to secure yield and tensile strength. The Si content is in the range of 0.4% or less to secure impact and fatigue properties at low temperatures. In addition, when the Si content exceeds 0.4%, Si may prevent diffusion of C to promote formation of the MA. In order to control the Si content to less than 0.05%, there may be a disadvantage in that a treatment time in a steelmaking process may greatly increase. Therefore, the Si content is in the range of 0.05 to 0.4%. The Si content is more preferably in the range of 0.05 to 0.2% in order to more stably secure toughness by minimizing the formation of MA.

Manganese (Mn): 1.0-2.0%

[0017] Mn may be added in an amount of 1.0% or more, since Mn has a relatively large effect on an increase in strength by solid solution strengthening. When the Mn content exceeds 2.0%, since toughness may be degraded due to formation of MnS inclusions or segregation of a central portion, the Mn content is in the range of 1.0 to 2.0%. The Mn content is more preferably in the range of 1.3 to 1.7% in consideration of an effect of increasing strength and a decrease in toughness due to the segregation.

Phosphor (P): 0.01% or less

[0018] Since P may be an element causing grain boundary segregation and may cause embrittlement of steel, an upper limit thereof needs to be 0.01%.

Sulfur (S): 0.003% or less

[0019] S may be mainly combined with Mn to form MnS inclusions, decreasing toughness at low temperature. Therefore, in order to secure toughness at low temperature and fatigue properties at low temperature, it is necessary to limit the S content to 0.003% or less.

Aluminum (Al): 0.015-0.04%

[0020] In the invention Al may be not only a major deoxidizer of steel, but also an element necessary for fixing N during strain aging. In order to fully acquire the effect, Al is added in an amount of 0.015% or more. When Al exceeds 0.04%, a fraction and a size of Al_2O_3 inclusions may increase to cause a decrease in the toughness at low temperature. In addition, similarly to Si, since the formation of MA in a base material and a weld heat affected zone degrades the toughness at low temperature and the fatigue properties at low temperature, the Al content is in the range of 0.015 to 0.04%. Al is more preferably in the range of 0.015 to 0.025% in order to more stably secure the toughness by minimizing the formation of MA.

Titanium (Ti): 0.005-0.02%

[0021] Ti may be an element that reduces solid solution N by forming Ti nitride (TiN) in combination with N causing strain aging. The Ti nitride may serve to contribute to miniaturization by inhibiting coarsening of a microstructure, and to improve toughness. In order to obtain the effect, Ti is added in an amount of at least 0.005%. When the Ti content exceeds 0.02%, precipitates may rather coarsen to cause destruction. In this case, solid solution Ti, which is not bonded with N, may remain to form Ti carbide (TiC), to degrade toughness of the base metal and toughness of the welded portion. Therefore, the Ti content is in the range of 0.005 to 0.02%. More preferably, Ti may have a range of 0.005 to 0.017% to prevent coarsening of nitride.

Copper (Cu): 0.35% or less (excluding 0)

[0022] Cu may be an element that does not significantly degrade impact properties, and improves strength by solid solution and precipitation. When the Cu content exceeds 0.35%, surface cracking of the steel plate due to thermal shock may occur. Therefore, the Cu content is in the range of 0.35% or less.

Nickel (Ni): 0.05-0.8%

[0023] Ni may be an element that may improve strength and toughness at the same time, although an effect of increasing strength is not great. Ni is added in an amount of 0.05% or more in order to sufficiently obtain the effect. Since Ni is a relatively expensive element, when the Ni content exceeds 0.8%, economic efficiency may be reduced. Therefore, the Ni content has a range of 0.05 to 0.8%. Ni has more preferably a range of 0.2 to 0.8% in a viewpoint of an increase in strength and toughness.

Niobium (Nb): 0.003-0.03%

[0024] Nb may be an element staying in a solid solution state or precipitating carbonitrides, suppressing recrystallization during rolling or cooling, reducing a grain size of a microstructure, and increasing strength. For the above effect, the Nb is added in an amount of at least 0.003%. When the Nb content exceeds 0.03%, C concentration may occur due to C affinity, to promote the formation of MA phase, and to degrade the toughness and fracture properties at low temperatures. Therefore, the Nb content is in the range of 0.003-0.03%.

Nitrogen (N): 0.002-0.008%

[0025] N, together with C, may be a main element causing strain aging, and it is desirable to keep its content as low as possible. In order to reduce deterioration of strain aging impact properties due to N, it is necessary to appropriately include Al, Ti, Nb, etc. When the N content is too high, since it is difficult to suppress the effect of strain aging, the N content is 0.008% or less. When the N content is less than 0.002%, toughness of the base metal and toughness of the welded portion may be degraded by causing solid solution strengthening or forming other precipitates in a state in which elements for suppressing the strain aging impact properties are added. Therefore, the N content lies in the range of 0.002 to 0.008%.

Calcium (Ca): 0.0002-0.0050%

[0026] When Ca is added to molten steel during a steelmaking process after Al deoxidation, Ca may be bonded to S which exists mainly as MnS to inhibit production of MnS, simultaneously with formation of globular-shaped CaS, to have an effect of suppressing cracks in a central portion of the steel material. Therefore, in order to form S which is added in the present invention into CaS sufficiently, 0.0002% or more is added. When the Ca content is more than 0.0050%, Ca remaining after forming CaS is bonded to O to produce coarse oxidative inclusions, which are stretched and fractured in rolling to serve as a crack initiation point at low temperatures. Therefore, the Ca content is in the range of 0.0002-0.0050%.

Chromium (Cr): 0.009% or less

[0027] Cr may be an element forming a strong carbide, may reduce fraction of ferrite, and may promote formation of hard phases, to degrade impact toughness. Therefore it is preferable to keep the Cr content as low as possible or not included, and in the invention an upper limit thereof is managed to 0.009%.

Molybdenum (Mo): 0.0009% or less

[0028] Mo, in a similar manner to Cr, may be also an element for forming a strong carbide, may reduce a fraction of ferrite, and may promote formation of hard phases, to degrade impact toughness. Therefore it is preferable to keep the Mo content as low as possible or not included, and in the present invention, an upper limit thereof is managed to 0.0009%.

[0029] The other component of the steel sheet is iron (Fe). Impurities of raw materials or manufacturing environments may be inevitably included in the steel sheet, and such impurities may not be removed from the steel sheet. Such impurities are well-known to those of ordinary skill in manufacturing industries, and thus specific descriptions of the impurities will not be given herein.

[0030] The microstructure of the thick steel plate produced according to the method of the invention includes 95 area% or more of ferrite having an average grain size of 10μm or less. The crystal grains of the ferrite as described above may be miniaturized to improve the strain aging impact properties at low temperature. When the fraction of the ferrite is less than 95 area%, it may be difficult to secure the effect. More preferably, the fraction of ferrite is 98 area% or more. The remainder of the microstructure may include at least one of cementite and MA, and the fraction thereof may be 5 area% or less, and more preferably 2 area% or less.

[0031] In addition, the ferrite may have a maximum grain size of 20um or less. When the maximum grain size of the ferrite exceeds 20 pm or less, it may be difficult to secure low-temperature strain aging impact properties targeted by the present invention.

[0032] The ferrite may consist of polygonal ferrite and acicular ferrite. Therefore, as described above, a hard phase that may be a starting point of the impact toughness may be minimized, and ferrite having good shock absorption may be configured as a microstructure, to secure shock and strain age shock properties at low temperature.

[0033] The thick steel plate, provided as described above, may have a yield strength of 350MPa or more, a tensile strength of 450MPa or more, an impact toughness of 200J or more at -60°C, and a strain aging impact toughness of 100J or more at -60°C, and may secure excellent low-temperature strain aging impact properties, as well as high yield strength. The strain aging impact toughness means an impact energy value measured after aging treatment at 250°C for 1 hour, after a tensile strain of 5 to 10% is applied.

[0034] In addition, the thick steel plate may have a thickness of 40mm or more. In the present invention, an upper limit of the thickness of the thick steel plate is not particularly limited, but may have, for example, a thickness of 100mm or less.

[0035] The thick steel plate of the present invention may be applied to the shipbuilding and offshore structural industries that require a bending process, a cold deformation process, and the like, and may contribute to have excellent strain aging impact properties to secure stability and extend a lifespan of the structure.

[0036] Hereinafter, a manufacturing method of the thick steel plate of this invention will be described in detail.

[0037] First, a steel slab having the alloy composition described above is reheated at 1020 to 1150°C. When the reheating temperature exceeds 1150°C, grains of austenite may be coarsened to deteriorate toughness, and when the reheating temperature is lower than 1020°C, Ti, Nb, and the like may not be sufficiently employed to cause a decrease in strength.

[0038] The reheated steel slab is subjected to a recrystallization zone rolling operation in 5 passes or fewer (including 0 passes) to obtain a bar. In the present invention, the recrystallization zone rolling operation during a hot-rolling process is performed only to match a width of the product. For example, in the present invention, it is possible to minimize the recrystallization zone rolling operation and maximize a non-recrystallization zone rolling operation to achieve grain refinement. When the recrystallization zone rolling operation exceeds 5 passes, there may be a problem that the total reduction amount in the non-recrystallization zone rolling operation is reduced. Therefore, in the present invention, it is necessary to omit or minimize the recrystallization zone rolling operation.

[0039] The bar is subjected to a non-recrystallization zone rolling operation at Ar3 or higher, and preferably about 750°C or higher, to obtain a hot-rolled steel material. When the rolling temperature is less than Ar3 during the non-recrystallization zone rolling operation, a structure anisotropy may be formed due to stretching of ferrite, to have a problem of deteriorating impact toughness.

[0040] A reduction amount in the non-recrystallization zone rolling operation is 90% or more (including 100%) of the sum of a reduction amount in the recrystallization zone rolling operation and the reduction amount in the non-recrystallization zone rolling operation. The recrystallization zone rolling operation may be performed in 5 passes or fewer (including 0 passes) as described above, the reduction amount in the non-recrystallization zone rolling operation may be performed at 90% or more, to realize grain refinement and secure excellent low temperature strain aging impact properties.

[0041] After the non-recrystallization zone rolling operation, cooling the hot-rolled steel material to 300 to 500°C at a cooling rate of 2 to 15°C/s, by a water-cooling process and the like, is further included. When the cooling rate is less than 2°C/s, it may be difficult to secure the target strength. When the cooling rate exceeds 15°C/s, a relatively large amount of hard phase, such as MA, bainite, and the like, may be formed in a manner that degrades toughness.

[0042] In order to obtain a more sufficient aging shock guarantee temperature, the cooling may not be performed after the non-recrystallization zone rolling operation. In this case, which is not within the scope of the invention as stated in the claim hereof, the tensile strength may drop slightly.

[Mode for Invention]

[0043] Hereinafter, the present invention 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 claim, and modifications and variations may be reasonably inferred therefrom.

(Example)

[0044] After preparing molten steel having the alloy composition shown in Table 1, using a continuous casting operation to produce a steel slab, the steel slab was reheated under the conditions shown in Table 2, hot-rolled, and cooled to prepare a thick steel plate. After measuring a microstructure and mechanical properties of the thick steel plate thus prepared, the results are shown in Table 3 below.

[Table 1]

Steel	Alloy Composition (wt%)													
	C	Si	Mn	P*	S*	Al	Ti	Cu	Ni	Nb	N*	Ca*	Cr	Mo
IS1"	0.078	0.203	1.47	77	17	0.023	0.012	0.25	0.63	0.012	35	16	0.008	0.0007
IS2	0.079	0.205	1.46	84	19	0.028	0.013	0.26	0.63	0.012	38	12	0.009	0.0009
IS3	0.065	0.213	1.56	75	20	0.022	0.0098	0.26	0.57	0.021	37	15	0.008	0.0008
IS4	0.072	0.168	1.51	65	21	0.018	0.01	0.25	0.67	0.018	35	14	0.008	0.0009
CS1**	0.105	0.198	1.48	84	18	0.025	0.011	0.27	0.61	0.023	41	12	0.008	0.0008
CS2	0.068	0.224	1.58	82	17	0.021	0.0099	0.26	0.51	0.019	90	16	0.009	0.0009
CS3	0.079	0.210	1.55	75	16	0.022	0.012	0.25	0.59	0.021	38	15	0.026	0.0009
CS4	0.08	0.215	1.56	83	19	0.024	0.011	0.24	0.58	0.022	37	14	0.008	0.007

(continued)

Steel	Alloy Composition (wt%)													
	C	Si	Mn	P*	S*	Al	Ti	Cu	Ni	Nb	N*	Ca*	Cr	Mo
P*, S*, N*, and Ca* are provided in ppm units.														
*IS: Inventive Steel, **CS: Comparative Steel														

[Table 2]

	Steel	Reheating Temp. (°C)	Pass No. in Recrystallization Zone Rolling Operation	Starting Temp. (°C) in Non-recrystallization Zone Rolling Operation	End Temp. (°C) in Non-recrystallization Zone Rolling Operation	Reduction Amount (%) in Non-recrystallization Zone Rolling Operation	Cooling End Temp. (°C)	Cooling Rate (°C/s)
IE1***	IS1*	1107	-	835	764	100	422	6.8
IE2	IS2	1110	-	845	762	100	384	7.9
IE3	IS3	1114	2	840	758	91	446	6.3
IE4	IS4	1112	2	853	759	90	451	7.1
NCE5*****	IS1	1123	-	849	758	100	-	-
CE1****	IS4	1123	8	851	764	50	398	6.9
CE2	CS1**	1109	-	832	755	100	368	8.6
CE3	CS2	1116	-	841	754	100	406	7.3
CE4	CS3	1118	-	852	751	100	415	6.8
CE5	CS4	1114	-	850	756	100	425	7.1
The reduction amount in the non-recrystallization zone rolling operation is a ratio relative to the sum of a reduction amount in the recrystallization zone rolling operation and the reduction amount in the non-recrystallization zone rolling operation								
*IS: Inventive Steel, **CS: Comparative Steel, ***IE: Inventive Example, ****CE: Comparative Example, *****NCE: Non-claimed Example								

[Table 3]

	Average Grain Size (μm) of Ferrite	Maximum Grain Size (μm) of Ferrite	Fraction (area%) of Ferrite	Fractio n (area%) of Balance	Yield Stren gth (MPa)	Tensi le Stren gth (MPa)	Elonga tion (%)	Impact Toughness (@ -60°C, J)	Strain Aging Impact Toughnes s (@ - 40°C, J)	Strain Aging Impact Toughness (@ -60°C, J)
IE1"	7.5	15	95.6	4.4	375	645	34	268	205	164
IE2	8.8	18	96.2	3.8	379	656	34	245	221	184
IE3	9.1	16	95.7	4.3	384	586	35	210	186	121
IE4	8.4	14	96.1	3.9	388	574	36	206	148	142
NCE5***	9.6	18	95.7	4.3	421	522	36	312	252	202
CE1**	24	42	78.6	21.4	382	633	30	154	86	22
CE2	9.6	19	84.2	15.8	392	643	31	98	24	18
CE3	8.7	18	95.2	4.8	376	634	30	84	26	15
CE4	9.4	17	91.4	8.6	412	635	29	58	22	8
CE5	9.2	19	93.4	6.6	409	645	28	68	18	8
The balance means one or more of cementite and MA.										
*IE: Inventive Example, **CE: Comparative Example, ***NCE : non-claimed example										

[0045] As can be seen from Tables 1 to 3, in cases of Inventive Examples 1 to 5 that satisfy the alloy composition and the manufacturing conditions proposed by the present invention, it can be confirmed that an average grain size of the ferrite was secured to have 10 um or less, and a fraction of the ferrite was secured to have 95 area%, to have a yield strength of 350MPa or more, a tensile strength of 450MPa or more, an impact toughness of 200J or more at -60°C, and a strain aging impact toughness of 100J or more at -60°C. In cases of Comparative Examples 1 to 3 that do not satisfy the alloy composition or the manufacturing conditions of the present invention, it can be seen that the desired strain aging impact toughness of the present invention was not secured.

[0046] In cases of Inventive Examples 1 and 2 satisfying the alloy composition, not subjected to a recrystallization zone rolling operation, and only subjected to a non-recrystallization zone rolling operation, it can be seen that fine microstructure and excellent mechanical properties were secured.

[0047] In cases of Inventive Examples 3 and 4 satisfying the alloy composition, subjected to a recrystallization zone rolling operation in two passes for width control of the product, and subjected to a non-recrystallization zone rolling operation, it can be seen that fine microstructure and excellent mechanical properties were secured.

[0048] In a case of Non-claimed Example 5 satisfying the alloy composition, subjected to a recrystallization zone rolling operation, and not subjected to a water cooling operation, it can be seen to have a slightly lower strength, but excellent strain aging impact properties, relative to a case in which the water cooling operation was performed.

[0049] In a case of Comparative Example 1 not satisfying the alloy composition of the present invention, subjected to a recrystallization zone rolling operation in 8 passes, and subjected to application of a conventional TMCP process, it can be seen that the low-temperature strain aging impact toughness is low due to the coarsening of ferrite grains.

[0050] In cases of Comparative Examples 2 and 3, respectively, in which the C and N contents exceed the conditions of the present invention, it can be seen that the low-temperature strain aging impact toughness is relatively low, and it is believed that the interstitial elements C and N were fixed to the dislocation to cause deteriorated toughness. In particular, in the case of Comparative Example 2, it can be seen that impact toughness was degraded due to an increase in pearlite by over-addition of C.

[0051] In cases of Comparative Examples 4 and 5, respectively, the Cr and Mo contents exceed the conditions of the present invention, although they satisfy the manufacturing conditions of the present invention, it can be seen that the low-temperature strain aging impact toughness is relatively low. This is believed to be due to a decrease in ferrite fraction and an increase in hard phase under the influence of strong carbide forming elements, Mo and Cr.

[0052] FIG. 1 is a captured photograph of a microstructure of Inventive Example 1. As can be seen in FIG. 1, in the case of Inventive Example 1 that satisfies the conditions of the present invention, it can be confirmed that grains of the microstructure were fine.

[0053] FIG. 2 is a captured photograph of a microstructure of Comparative Example 1. As can be seen in FIG. 2, in the case of Comparative Example 1 that does not satisfy the conditions of the present invention, it can be confirmed that grains of the microstructure were coarse.

Claims

1. A method of manufacturing a thick steel plate having excellent low-temperature strain aging impact properties, comprising:

   reheating a steel slab consisting of, by weight, C: 0.04 to 0. 08%, Si: 0.05 to 0.4%, Mn: 1.0 to 2.0%, P: 0.01% or less, S: 0.003% or less, Al: 0.015 to 0.04%, Ti: 0.005 to 0.02%, Cu: 0.35% or less, excluding 0, Ni: 0.05 to 0.8%, Nb: 0.003 to 0.03%, N: 0.002 to 0.008%, Ca: 0.0002 to 0.0050%, Cr: 0.009% or less, Mo: 0.0009% or less, a balance of Fe and other inevitable impurities, at 1020 to 1150°C;
   performing a recrystallization zone rolling operation of the reheated steel slab in 5 passes or fewer, including 0 passes, to obtain a bar;
   performing a non-recrystallization zone rolling operation on the bar at Ar3 or higher to obtain a hot-rolled steel material, wherein a reduction amount in the non-recrystallization zone rolling operation is 90% or more, including 100%, of the sum of a reduction amount in the recrystallization zone rolling operation and the reduction amount in the non-recrystallization zone rolling operation; and cooling the hot-rolled steel material to 300 to 500°C at a cooling rate of 2 to 15°C/s, after the non-recrystallization zone rolling operation.

Patentansprüche

1. Verfahren zur Herstellung einer dickwandigen Stahlplatte mit ausgezeichneten Niedrigtemperatur-Reckalterungs-impakteigenschaften, umfassend:

Wiedererwärmen einer Stahlbramme, bestehend aus, in Gewichtsprozent, C: 0,04 bis 0,08 %, Si: 0,05 bis 0,4 %, Mn: 1,0 bis 2, 0 %, P: 0,01 % oder weniger, S: 0,003 % oder weniger, Al: 0,015 bis 0,04 %, Ti: 0,005 bis 0,02 %, Cu: 0,35 % oder weniger, ausgenommen 0, Ni: 0,05 bis 0,8 %, Nb: 0,003 bis 0,03 %, N: 0,002 bis 0,008 %, Ca: 0,0002 bis 0,0050 %, Cr: 0,009 % oder weniger, Mo: 0,0009 % oder weniger, verbleibende Anteile von Fe und anderen unvermeidbaren Verunreinigungen, bei 1020 bis 1150 °C;
Durchführen eines Rekristallisationszonen-Walzvorgangs der wiedererwärmten Stahlbramme in 5 Stichen oder weniger, einschließlich oder 0 Stichen, um einen Stab zu erhalten;
Durchführen eines Nicht-Rekristallisationszonen-Walzvorgangs an dem Stab bei Ar3 oder höher, um ein warmgewalztes Stahlmaterial zu erhalten, wobei ein Reduktionsbetrag in dem Nicht-Rekristallisationszonen-Walzvorgang 90 % oder mehr, einschließlich 100 %, der Summe eines Reduktionsbetrags in dem Rekristallisationszonen-Walzvorgang und des Reduktionsbetrags in dem Nicht-Rekristallisationszonen-Walzvorgang beträgt;
und Abkühlen des warmgewalzten Stahlmaterials auf 300 bis 500 °C mit einer Abkühlungsrate von 2 bis 15 °C/s nach dem Nicht-Rekristallisationszonen-Walzvorgang.

Revendications

1. Procédé de fabrication d'une tôle en acier épaisse présentant d'excellentes propriétés d'impact de vieillissement sous contrainte à basse température, comprenant :

le réchauffement d'une bande en acier constituée, en poids, de C : 0,04 à 0,08 %, Si : 0,05 à 0,4 %, Mn : 1,0 à 2,0 %, P : 0,01 % ou moins, S : 0,003 % ou moins, Al : 0,015 à 0,04 %, Ti : 0,005 à 0,02 %, Cu : 0,35 % ou moins, à l'exclusion de 0, Ni : 0,05 à 0,8 %, Nb : 0,003 à 0,03 %, N : 0,002 à 0,008 %, Ca : 0,0002 à 0,0050 %, Cr : 0,009 % ou moins, Mo : 0,0009 % ou moins, un équilibre de Fe et d'autres impuretés inévitables, entre 1 020 et 1 150 °C ;
la réalisation d'une opération de laminage dans une zone de recristallisation de la bande en acier réchauffée en 5 passes ou moins, y compris 0 passe, pour obtenir une barre ;
la réalisation d'une opération de laminage dans une zone de non-recristallisation sur la barre à Ar3 ou plus pour obtenir un matériau en acier laminé à chaud, dans lequel un taux de réduction dans l'opération de laminage dans une zone de non-recristallisation est de 90 % ou plus, y compris 100 %, de la somme d'un taux de réduction dans l'opération de laminage dans une zone de recristallisation et du taux de réduction dans l'opération de laminage dans une zone de non-recristallisation ; et le refroidissement du matériau en acier laminé à chaud à 300 à 500 °C à une vitesse de refroidissement de 2 à 15 °C/s, après l'opération de laminage dans une zone de non-recristallisation.

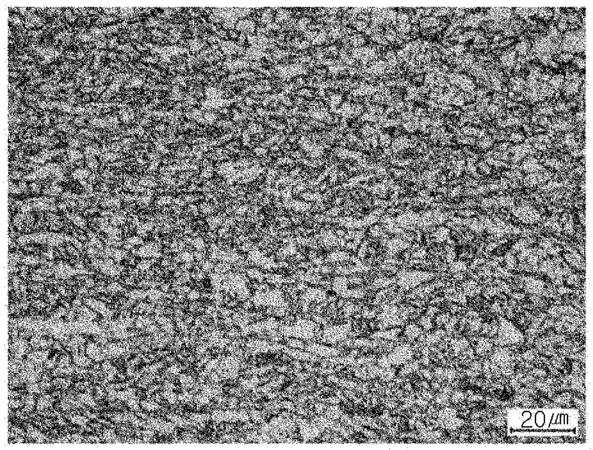

FIG. 1

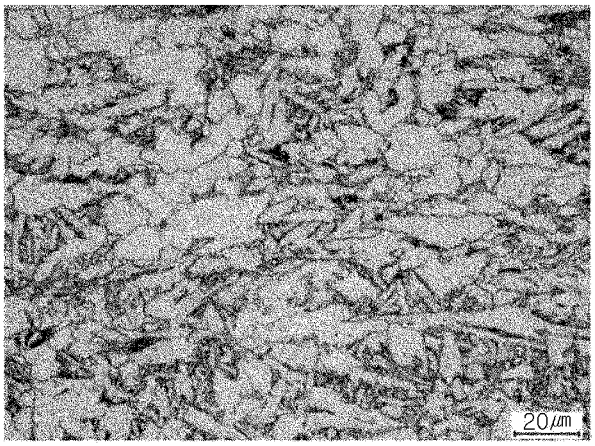

FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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