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

(11) EP 2 843 073 A1

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

(43) Date of publication:
04.03.2015 Bulletin 2015/10

(21) Application number: **13886145.5**

(22) Date of filing: **13.06.2013**

(51) Int Cl.:
C22C 38/00 (2006.01) ***C22C 38/58*** (2006.01)
B22D 11/22 (2006.01) ***C21D 8/02*** (2006.01)

(86) International application number:
PCT/JP2013/066349

(87) International publication number:
WO 2014/199488 (18.12.2014 Gazette 2014/51)

(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

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(54) ULTRAHIGH-TENSILE-STRENGTH STEEL PLATE FOR WELDING

(57) A steel plate includes, as a chemical composition, by mass%, C: 0.015% to 0.045%, Mn: 1.80% to 2.20%, Cu: 0.40% to 0.70%, Ni: 0.80% to 1.80%, Nb: 0.005% to 0.015%, Mo: 0.05% to 0.25%, Ti: 0.005% to 0.015%, B: 0.0004% to 0.0020%, N: 0.0020% to 0.0060%, and O: 0.0015% to 0.0035%, in which a number of oxide grains having an equivalent circle diameter of 2 μm or more is 20 particles/mm^2 or less and a number of Ti oxides having an equivalent circle diameter of 0.05 μm to 0.5 μm is 1.0×10^3 particles/mm^2 to 1.0×10^5 particles/mm^2 at a thickness center portion of a cross section in a thickness direction.

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Description

[Technical Field of the Invention]

[0001] The present invention relates to an ultrahigh tensile strength steel plate for a large welded structure such as an offshore structure or the like which requires a high degree of safety, having excellent weldability and toughness of a heat-affected zone.

[Related Art]

[0002] In recent years, in response to strong global energy demand, the development of marine resources such as oil, natural gas, or the like has been activated. Due to the aforementioned circumstance, an increase in the size of an offshore structure has been pursued due to excavation and production efficiency and severe development conditions. Therefore, there has been a demand for increasing the thickness and strength of steel. In addition, a high degree of safety with regard to against fracture has been required for the offshore structure installed on the sea and excellent weldability and toughness of a heat-affected zone in a steel plate are in demand.

[0003] Generally, weldability and toughness of a heat-affected zone of a steel plate tend to deteriorate as the thickness and the strength increase. This is because a large amount of an alloy element which deteriorates the toughness of the heat-affected zone has to be added to ensure strength. While weldability has a wide range of meanings, the weldability generally indicates the hardenability of a heat-affected zone and weld cold crack sensitivity and is indicated by various component parameters such as a carbon equivalent Ceq and a weld crack sensitivity composition P_{CM} in many cases. The greater the amount of the alloy components is, the higher the indices are. Thus, the hardenability of the heat-affected zone and weld cold crack sensitivity increase and generally, the weldability deteriorates. It is known that the toughness of the heat-affected zone is not always consistent with the values of the indices of the weldability but has a high correlation with the values of the indices.

[0004] As described above, usually, an increase in the thickness and/or the strength of the steel plate is contradictory to a direction of increasing weldability and toughness of the heat-affected zone and there has been a problem of component design or production technique for attaining the contradictory properties of the steel plate.

[0005] As a method of attaining an increase in the thickness and/or strength of a steel plate without deteriorating weldability, that is, without increasing the amount of chemical components more than needed, there is a thermo-mechanical treatment, that is, thermo-mechanical control process (TMCP) and thermal refining treatment (quenching-tempering treatment) for boron (B)-added steel, which are widely known for any person skilled in the art needless to particularly disclose techniques here. However, it is also true that the effect is not sufficient even by the respective methods.

[0006] TMCP is for controlling the overall processes of heating-rolling-cooling for producing steel and a water cooling process that is also referred to as accelerated cooling or control cooling is effective to increase the strength of thick material after rolling. However, due to a physical phenomenon called thermal conduction, a sufficient cooling rate cannot be obtained at a thickness center portion of the thick material by water cooling, and it is difficult to ensure an increase in thickness and strength with a low composition.

[0007] On the other hand, it is known that since boron (B) used in refined steel having high strength is segregated on prior-austenite grain boundaries in a solid solution state, the hardenability of the steel is significantly increased even with a trace in the order of ppm, and thus, boron is effective to increase the strength. However, this also represents that the hardenability of the heat-affected zone is significantly increased at the same time. In the offshore structure which requires especially a high degree of safety (high fracture toughness of a heat-affected zone), weld heat input is limited being relatively low during the construction and the hardenability is further increased. The hardenability of the heat-affected d zone has a high correlation with the weld cold crack sensitivity and the toughness of the heat-affected zone as described above, and there has been a problem in the unconditional utilization of boron (B). In addition, when high hardenability of boron (B) is utilized, the effect is exhibited only under the presence of boron (B) in a solid solution state, and thus, a component for controlling precipitation of a boron compound, and process control, are necessary. In the combination with TMCP, there has been a case to which findings in the refining treatment cannot be applied as they are. The production by refining treatment, that is, quenching-tempering treatment is disadvantageous in terms of a heat treatment period or cost compared to TMCP. Further, it is fact that non-refining, that is, the attainment of TMCP has been actually socially requested from the viewpoint of environmental load and energy saving in recent years.

[0008] Under the circumstances, as steel for an offshore structure having excellent crack tip opening displacement CTOD properties of a welded joint zone having the same thickness and yield strength as those of a main target of the present invention which will be described later, for example, in Patent Document 1, there is disclosed an invention related to Cu-precipitated steel including 0.8% or more of Cu, which is relatively high. However, when a large amount of Cu alone is added, Cu cracking occurs at the time of heating or hot-rolling, and thus, there is a problem of having a difficulty in production.

[Prior Art Document]

[Patent Document]

[0009] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2011-1625

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0010] The present invention is made in consideration of the above circumstances and an object thereof is to provide an ultrahigh tensile strength steel plate for a large welded structure such as an offshore structure or the like which requires a high degree of safety, having excellent weldability and toughness of a heat-affected zone.

[0011] The main target is a steel plate used for an offshore structure which requires the crack tip opening displacement (CTOD) properties of a welded joint zone with properties of a thickness of 50 mm to 100 mm, a tensile strength of 600 MPa to 700 MPa, a yield strength of 500 MPa to 690 MPa, and the lowest CTOD value of crack tip opening displacement of 0.25 mm or more in a heat-affected zone. It is preferable that the lowest CTOD value is high to ensure sufficient safety against fracture. The usage is not particularly limited and as for the evaluation of the toughness of the heat-affected zone, it is considered that CTOD property evaluation is severer evaluation method compared to Charpy impact properties evaluation, and thus, the steel plate for an offshore structure is set as the main target. Accordingly, it is needless to say that the present invention can be widely applied as a steel plate for welded structures such as vessels, steel frames, bridges, various tanks, or the like.

[Means for Solving the Problem]

[0012] In order to solve various problems that have been pointed out in the related art, on the assumption of TMCP, a method of effectively utilizing boron (B) has been intensively searched and investigated and the inventors found the best method of improving the toughness of the heat-affected zone without deteriorating weldability. The main features are (a) B-N-Ti amount balance optimization for ensuring solid soluted boron (B), (b) C content ultra reduction for alleviating the hardenability of the heat-affected zone by (solid soluted) B, (c) P_{CM} optimization for ensuring the strength, weldability and toughness of the heat-affected zone, (d) Al-free Ti deoxidation for ensuring the toughness of the heat-affected zone, (e) oxide (O) reduction under the Al-free statement for suppressing a coarse oxide, and the like. Since the features are not independent events and have a close relationship among each other, the features are not easily attained at the same time and can be realized by a systematic and precise test conducted by the inventors for the first time and thus, the present invention has been completed.

[0013] The gist of the present invention is as follows.

[0014]

(1) According to a first aspect of the present invention, there is provided a steel plate including, as a chemical composition, by mass%, C: 0.015% to 0.045%, Mn: 1.80% to 2.20%, Cu: 0.40% to 0.70%, Ni: 0.80% to 1.80%, Nb: 0.005% to 0.015%, Mo: 0.05% to 0.25%, Ti: 0.005% to 0.015%, B: 0.0004% to 0.0020%, N: 0.0020% to 0.0060%, O: 0.0015% to 0.0035%, Si: 0% to 0.40%, P: 0.008% or less, S: 0.005% or less, Al: 0% to 0.004%, Cr: 0% to 0.30%, V: 0% to 0.06%, Mg: 0% to 0.0050%, and a balance consisting of Fe and unavoidable impurities, wherein a value expressed by a following Expression 1 is more than 2.0, a value expressed by a following Expression 2 is 0% or more, FB expressed by a following Expression 3 is 0.0003% or more, a P_{CM} value which is a weld cracking parameter expressed by a following Expression 4 is 0.18% to 0.23%, and a number of oxide grains having an equivalent circle diameter of 2 μm or more is 20 particles/mm^2 or less and a number of Ti oxides having an equivalent circle diameter of 0.05 μm to 0.5 μm is 1.0×10^3 particles/mm^2 to 1.0×10^5 particles/mm^2 at a thickness center portion of a cross section in a thickness direction,

$$[Ni]/[Cu] \text{ ... Expression 1,}$$

$$[N]-[Ti]/3.4 \quad ... \text{ Expression 2},$$

$$FB = [B] - 0.77 \times ([N] - 0.29 \times ([Ti] - 2 \times ([O] - 0.89 \times [Al]))) \text{ ... Expression 3},$$

$$P_{CM} = [C] + [Si]/30 + [Mn]/20 + [Cu]/20 + [Ni]/60 + [Cr]/20 + [Mo]/15 + [V]/10 + 5[B] \text{ ... Expression 4},$$

here, [C], [Si], [Mn], [Cu], [Ni], [Cr], [Mo], [V], [Ti], [B], [N], [O], and [Al] represent respectively C, Si, Mn, Cu, Ni, Cr, Mo, V, Ti, B, N, O, and Al contents by mass%,

however, when the term of ([O] - 0.89 × [Al]) in the Expression 3 is 0 or less, the term of ([O] - 0.89 × [Al]) in the Expression 3 is set to 0 to calculate the FB, also, when the term of ([Ti] - 2 × ([O] - 0.89 × [Al])) in the Expression 3 is 0 or less, the term of ([Ti] - 2 × ([O] - 0.89 x [Al])) in the Expression 3 is set to 0 to calculate the FB, further, when the term of ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) in the Expression 3 is 0 or less, the term of ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) in the Expression 3 is set to 0 to calculate the FB, and still further, when FB ≤ 0, FB = 0.

(2) According to the steel plate according to (1), a Bp expressed by a following Expression 5 may be 0.09% to 0.30%.

$$Bp = (884 \times [C] \times (1 - 0.3 \times [C]^2) + 294) \times FB \text{ ... Expression 5}$$

(3) The steel plate according to (1) or (2) may further include, as the chemical composition, by mass%, Si: limited to 0.15% or less.

(4) The steel plate according to any one of (1) to (3) may further include, as the chemical composition, by mass%, Mg: limited to less than 0.0003%.

(5) According to the steel plate according to any one of (1) to (4), a thickness may be 50 mm or more and 100 mm or less, a tensile strength may be 600 MPa or more and 700 MPa or less, and a yield strength may be 500 MPa or more and 690 MPa or less.

[Effects of the Invention]

[0015] According to the present invention, it is possible to provide the ultrahigh tensile strength steel having excellent weldability and toughness of the heat-affected zone at a low cost and also possible to further increase safety while the size of a welded structure such as an offshore structure can be increased.

[Embodiments of the Invention]

[0016] Hereinafter, details of the present invention will be described.

[0017] An object of the present invention is to provide an ultrahigh tensile strength steel for a large welded structure such as an offshore structure or the like which requires a high degree of safety, having excellent weldability and toughness of the heat-affected zone, and a steel plate having a thickness of 50 mm to 100 mm, a tensile strength of 600 MPa to 700 MPa, a yield strength of 500 MPa to 690 MPa, and the lowest CTOD value of crack tip opening displacement of 0.25 mm or more in the heat-affected zone is a main target.

[0018] First, the limited range and the reasons for limitation of the steel components of the ultrahigh tensile strength steel of the present invention will be described. Here, in the following description, % represents mass%.

C: 0.015% to 0.045%

[0019] In the present invention in which high hardenability of B is utilized, it is necessary to suppress an amount of C to be relatively small in order to suppress excessive hardenability of the heat-affected zone. However, when an amount of C is excessively small, an amount of an alloy element for compensating for the strength (tensile strength) has to be increased and thus, economical efficiency is lost. In order to obtain stable strength as the steel that is thick and has a yield strength of 500 MPa to 560 MPa class (which is a strength grade as a steel type and does not indicate an actual yield strength range) as the target of the present invention while an alloy cost is suppressed, the amount of C is limited to 0.015% or more in the present invention. From the viewpoint of economical efficiency, the lower limit thereof may be 0.018%, 0.020%, 0.023% or 0.025%. On the other hand, when the amount of C exceeds 0.045%, the hardness of the heat-affected zone becomes excessive with the effect of B and the toughness of the heat-affected zone is deteriorated. Thus, the upper limit is set to 0.045%. In order to reduce the hardness of the heat-affected zone, the upper limit thereof may be set to 0.042%, 0.040%, 0.037%, or 0.035%.

Si: 0% to 0.40% or less

[0020] Si is unavoidably included in the steel and particularly promotes formation of hard and brittle martensite-austenite (MA) constituent (hereafter, abbreviated to MA) and deteriorates the toughness of the heat-affected zone. Therefore, the smaller the Si is, the more preferable it is. In the present invention in which the amount of C is limited to be relatively small, when Si is included in an amount of up to 0.40%, the MA formation amount is small, and the amount is allowable from the viewpoint of the toughness of the heat-affected zone. However, in consideration of various welding conditions as steel for a welded structure, needless to say, the smaller the amount is, the more preferable it is. The upper limit thereof may be 0.30%, 0.25%, 0.20%, 0.15%, or 0.10% or less. The lower limit of Si does not need to be defined and the lower limit thereof is set to 0%. Si may be included to improve the toughness of the base metal of the steel plate or deoxidize the steel, and as necessary, the lower limit thereof may be set to 0.01%, 0.02%, or 0.03%.

Mn: 1.80% to 2.20%

[0021] Mn is a relatively inexpensive element, but has a great effect to increase the strength and the toughness of the base metal and the heat-affected zone is relatively less adversely affected by Mn. In the present invention in which Al-free Ti deoxidation is performed, it is important to form intragranular ferrite with Ti oxides or the like as nuclei in the heat-affected zone to improve the toughness of the heat-affected zone. However, at this time, Mn also plays an important role. The role is to promote ferrite transformation in such a manner that MnS is precipitated in the Ti oxides to form a Mn depletion region in the vicinity thereof and the transformation temperature is increased higher than that of the matrix. In comprehensive consideration of the strength and toughness of the base metal, the toughness of the heat-affected zone, and further, an alloy cost, the amount of Mn is limited to 1.80% or more in the present invention. The lower limit thereof does not have a critical metallurgical and technical meaning and is limited to make component properties clear within a range in which excellent properties that are targeted in the present invention are exhibited. For the purpose of improving the properties, the lower limit may be set to 1.85% or 1.90%. Mn is an inexpensive element and is attempted to be maximally utilized. However, when the amount of Mn is excessive, center segregation or microsegregation of a continuously cast slab is promoted, and a local embrittled region is formed and thus, it is highly likely to deteriorate the toughness of the base metal or the heat-affected zone. Therefore, the amount of Mn is limited to 2.20% or less. In order to improve the toughness of the base metal or the heat-affected zone, the upper limit thereof may be 2.15% or 2.10%.

P: 0.008% or less, and S: 0.005% or less

[0022] P and S are unavoidably included as impurities and it is preferable that the amount of P and S be small in terms of the toughness of the base metal and the toughness of the HAZ. However, there is limitation in industrial production, and thus, the upper limits of P and S are respectively set to 0.008% and 0.005%. In order to obtain more satisfactory toughness of the HAZ, the upper limit of P may be 0.006%, 0.005%, or 0.004%, and the upper limit of S may be 0.004%, 0.003%, or 0.002%, respectively. P and S are unavoidable impurities and the lower limits of P and S do not need to be defined. If needed, the lower limits of P and S may be 0%.

Cu: 0.40% to 0.70%

[0023] While improving the strength of the base metal, Cu deteriorates the toughness of the base metal and the heat-affected zone relatively less to a small degree and thus, is a useful element. In the ultrahigh tensile strength steel which is the target of the present invention, it is preferable to add 0.40% or more of Cu. In order to improve the strength of the base metal, the lower limit thereof may be 0.45%, 0.50%, or 0.55%. When the amount of Cu exceeds 0.70%, a precipitation hardening phenomenon is exhibited and the material properties of the steel, particularly, the strength is significantly changed in a discontinuous manner. Therefore, in the present invention, the amount of Cu is limited to 0.70% or less as a range in which the strength change is easily controlled in a continuous manner. By limiting the amount of Cu to

0.7% or less, the effect of almost eliminating risk of the occurrence of Cu cracking at the time of hot rolling with the amount of Ni which will be described later is attained. As necessary, the upper limit thereof may be limited to 0.65%, 0.60%, or 0.55%.

Ni: 0.80% to 1.80%

[0024]

$$[Ni]/[Cu] > 2.0 \ldots \text{Expression 1}$$

[0025] Ni is known as a highly toughening element and is effective to improve the strength and the toughness of the base metal with less deterioration in the toughness of the heat-affected zone. Therefore, in the ultrahigh tensile strength steel as in the present invention, Ni is a very useful element. Particularly, in the ultralow carbon chemical composition as in the present invention, strength compensation by an alloy element is essential and it is necessary to include at least 0.80% or more of Ni. In order to improve the toughness of the heat-affected zone, the lower limit thereof may be 0.90%, 1.00%, 1.05%, or 1.10%. On the other hand, Ni is an expensive alloy and thus, the content is preferably suppressed to the minimum in which required properties such as strength, toughness, and the like can be obtained. In consideration of the target strength and maximum thickness (100 mm) of the present invention, 1.80% of Ni is required at most and the upper limit thereof is set to 1.80%. However, it is needless to say that the upper limit is not a property or metallurgical limit. As necessary, the upper limit thereof may be limited to 1.75%, 1.70%, 1.65%, 1.60%, 1.55%, or 1.50%. In the steel of the present invention including a slightly large amount of Cu as described above, it is effective to include Ni exceeding 2.0 with respect to the amount of Cu to suppress Cu cracking of a cast piece, and Ni is limited to $[Ni]/[Cu] > 2.0$ in Claim 1.

Nb: 0.005% to 0.015%

[0026] Nb is an effective element to obtain a controlled rolling effect which is effective for structure refinement by expanding an austenite non-recrystallization temperature region to a high temperature region in a rolling process. The structure refinement is an effective method for improving both strength and toughness. At least 0.005% of Nb is necessarily included to reliably obtain the effect. As necessary, the lower limit thereof may be 0.006%, 0.007%, or 0.008%. Nb which exhibits such a very useful effect in a base metal increases the hardness of the heat-affected zone to promote MA formation, and thus, is harmful to the toughness. Therefore, the upper limit has to be suppressed to 0.015%. In order to improve the toughness of the heat-affected zone, the upper limit thereof may be 0.013%, 0.011%, or 0.010%.

Mo: 0.05% to 0.25%

[0027] Mo is extremely effective from the viewpoint of improving the strength of the base metal, and is an essential element in the thick high strength steel plate as in the present invention. Particularly, in the present invention in which B is utilized, a higher hardenability improving effect is exhibited by including both Mo and B simultaneously. In order to obtain such excellent effect of Mo, at least 0.05% of Mo is necessarily included. The lower limit thereof may be 0.07%, 0.09%, 0.11%, or 0.13% to reliably exhibit the hardenability improving effect. However, the effect is significant but excessive addition causes a remarkable increase in the hardness and remarkably promotion of MA formation, and thus, it is necessary to limit the amount of Mo to 0.25% or less. In order to suppress MA formation, the upper limit thereof may be 0.23%, 0.21%, 0.19%, or 0.17%.

Ti: 0.005% to 0.015%

[0028]

$$[N] - [Ti]/3.4 \geq 0\% \ldots \text{Expression 2}$$

[0029] The present invention is an Al-free and Ti-deoxidized steel. It is necessary to include at least 0.005% of Ti since the steel needs to be deoxidizes and the microstructure is refined by forming Ti oxides, and forming intragranular ferrite using the Ti oxides as nuclei in the heat-affected zone. In order to improve the toughness of the heat-affected zone, the lower limit thereof may be 0.006% or 0.007%. However, when the content increases and is stoichiometrically excessive with respect to N, it is highly likely to form TiC by excessive Ti after nitride formation and deteriorate the toughness of the heat-affected zone. Thus, the upper limit is set to 0.015%. In addition, at the same time, from the viewpoint of preventing the TiC precipitation as much as possible, the stoichiometrical relationship between Ti and N is limited to [N] - [Ti]/3.4 ≥ 0%, which represents excess N (lack of Ti) in Claim 1. Here, Ti consumption by deoxidization has to be considered exactly, but it is experimentally confirmed that complication is avoided and also, there is no great influence substantially. In order to obtain a value of Expression 2 of 0% or more, the upper limit of Ti may be 0.013%, 0.012%, 0.011%, or 0.010%.

B: 0.0004% to 0.0020%

[0030]

$$FB = [B] - 0.77 \times ([N] - 0.29 \times ([Ti] - 2 \times ([O] - 0.89 \times [Al]))) \geq 0.0003\% \ldots$$

Expression 3

[0031] B is one of important elements in the present invention. The hardenability improving effect of B is very high and an alloy element can be significantly suppressed by utilizing B. Therefore, it is necessary that the amount of B is at least 0.0004%. As necessary, the lower limit thereof may be 0.0005%, 0.0006%, or 0.0007%. However, it is not sufficient to simply define only the B content. This is because that B has to be in a solid solution state to utilize the hardenability of B. B easily forms nitrides and a stoichiometrical balance between B and N is important. However, Ti has higher nitride forming capacity than B, and thus, considering the fact, B is limited to FB = [B] - 0.77 × ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) ≥ 0.0003% in Claim 1. Even when B is included more than needed, the effect is saturated and thus, the inventors have set the upper limit to 0.0020% as a range that is experimentally confirmed for a range in which the properties of the steel is not adversely affected. However, the value does not need to have critical significance. As necessary, the upper limit thereof may be limited to 0.0018%, 0.0016%, 0.0015%, or 0.0014%.

[0032] For the purpose of ensuring B that is present in a solid solution state in the steel (effective B), it has been found that 0.0003% or more of the FB as a parameter indicating the amount of the effective B defined by the Expression 3 is required. The FB may be set to 0.0004% or more, or 0.0005% to more effectively utilize B.

[0033] The upper limit of FB = [B] - 0.77 × ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) is not particularly limited, but is naturally limited from the limitation range of each element.

[0034] However, when the term of ([O] - 0.89 × [Al]) in the Expression 3 is 0 or less, the term of ([O] - 0.89 × [Al]) in the Expression 3 is set to 0 to calculate the FB.

[0035] In addition, in the Expression 3, when the term of ([Ti] - 2 × ([O] - 0.89 × [Al])) in the Expression 3 is 0 or less, the term of ([Ti] - 2 × ([O] - 0.89 × [Al])) in the Expression 3 is set to 0 to calculate the FB.

[0036] Further, when the term of ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) in the Expression 3 is 0 or less, the term of ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) in the Expression 3 is set to 0 to calculate the FB.

[0037] Still further, when FB ≤ 0, FB = 0.

[0038] In addition, the Expression 3 is an expression for obtaining the amount of the solid soluted B (the amount of effective B: FB) in the steel obtained from a stoichiometric ratio in consideration of a bonding force strength between the respective elements. The upper limit of the FB does not need to be defined particularly but may be 0.0010%.

[0039] As a result of further investigation, it is found that a B parameter Bp which is defined by Expression 5 as a parameter for avoiding an increase the hardness of the HAZ due to B is preferably 0.09% to 0.30%.

$$Bp = (884 \times [C] \times (1 - 0.3 \times [C]^2) + 294) \times FB \ldots \text{Expression 5}$$

[0040] Here, Bp is an empirical equation derived from the analysis by testing plural pieces of molten steel at an experimental laboratory and is parameterized by (the highest hardness estimated by amount of C) x (FB contribution). As the FB increases, the hardness of the HAZ tends to be increased. Particularly, the CTOD properties are significantly affected as this case. When Bp exceeds 0.30%, the hardness of a fusion line (FL) is remarkably increased in some cases, and thus, it has been found that the Bp is preferably limited to 0.30% or less to satisfy 0.25 mm or more that is the target value of the CTOD properties. As necessary, the upper limit of the Bp may be 0.27% or 0.25%. When the FB is 0.0003% or more in the welded steel according to the embodiment, the Bp has to be 0.09% or more, and thus, Bp of less than 0.09% within a region in which the effect of the solid soluted B targeted in the welded steel according to the embodiment cannot be obtained. Therefore, the Bp may be 0.09% or more. As necessary, the lower limit of the Bp may also be 0.12% or 0.15%.

N: 0.0020% to 0.0060%

[0041] N is an element which is unavoidably included in steel production and the reduction of N more than needed increases a load on steel production and is not preferable in terms of industrial production. N rather forms nitrides with the addition of Ti. In addition, the nitrides are stable at a high temperature and thus, have an effect of pinning austenite grain growth coarsening at the time of heating before hot-rolling the steel or in the heat-affected zone that is slightly away from the fusion line. Therefore, it is preferable that 0.0020% or more of N be included. However, when the amount of N is excessive, N is bonded with B to form nitrides as described above, and thus, the hardenability improving effect of B is highly likely to be reduced. From the above-described absolute amount and stoichiometric relationship between B and Ti, the upper limit is naturally limited, but additionally, when the amount of N exceeds 0.0060%, a surface defect occurs at the time of producing a steel piece. Thus, the upper limit is set to 0.0060%. The upper limit is preferably 0.0055% or less, and more preferably 0.005% or less.

0:0.0015% to 0.0035%

[0042] From the formability of the Ti oxides as nuclei for forming intragranular ferrite in the heat-affected zone, 0.0015% or more of O is required. However, when the amount of O is excessive, the size or the number of the oxides excessively increases and the oxides are highly likely to act as a starting point of brittle fracture. As a result, the toughness is deteriorated. Thus, it is necessary that the upper limit be limited to 0.0035%. In order to obtain more satisfactory stable toughness of the heat-affected zone, the amount of O is preferably 0.0030% or less, and more preferably 0.0028% or less, or 0.0025% or less.

Al: 0% to 0.004%

[0043] In the present invention of the Al-free and Ti deoxidation steel, Al is one of unavoidable impurities. The reason for limiting the upper limit in Claim 1 is that when the content of Al exceeds 0.004% even being unavoidably included, the composition of the oxides is changed and is highly likely not to function as the nuclei for intragranular ferrite, and thus, the amount of Al is limited to 0.004% or less. As necessary, the upper limit thereof may be 0.003% or 0.002%. The lower limit of the amount of Al does not need to be defined particularly, and the lower limit thereof is 0%. However, Al is mixed during the refining process of the steel in some cases, and thus, the lower limit thereof may be 0.0001% or 0.0003%.

[0044] The steel according to the embodiment also includes a balance consisting of Fe and unavoidable impurities in addition to the above components. Here, the impurities are components that are mixed on account of various factors in the production process including raw materials such as ore or scrap when steel is produced on an industrial scale and are allowed to be contained within the range such that the components do not exert an adverse influence on the present invention.

[0045] The steel plate according to the embodiment may include one or two types or more of Cr, V, Ca, Mg and REM, in addition to the above components. The lower limits of the components do not need to be defined particularly and the lower limits thereof are 0%. In addition, even when the alloy components are intentionally added or mixed as impurities, it is interpreted that the steel is within the scope of the Claims as long as the contents thereof are within the scope of the Claims.

Cr: 0% to 0.30%

[0046] Cr is set to 0.30% or less since Cr deteriorates the CTOD properties of the heat-affected zone. In order to improve the CTOD properties, the upper limit thereof may be 0.20%, 0.15%, 0.10%, or 0.05%. The lower limit of the amount of Cr does not need to be defined particularly, and the lower limit thereof is 0%. However, there is a case that Cr is mixed as an impurity and thus, the lower limit thereof may be 0.001%.

V: 0% to 0.06%

[0047] V is an effective element to improve the strength of the base metal. However, when the amount of V exceeds 0.06%, the CTOD properties are deteriorated, and thus, as a range in which the CTOD properties are not significantly deteriorated, the upper limit is set to 0.06% or less. In order to ensure superior CTOD properties, the upper limit thereof may be 0.04%, 0.02%, or 0.01%. The lower limit of the amount of V does not need to be defined particularly, and the lower limit thereof is 0%. However, even when V is mixed as an impurity, the lower limit thereof may be 0.001%.

Mg: 0% to 0.0050%

[0048] Mg can be included as necessary. When Mg is included, fine Mg-containing oxides are formed and thus, it is effective in γ grain size refinement. However, when the Mg content exceeds 0.0050%, the number of oxides is excessively increased and ductility is reduced. Thus, the upper limit thereof is set to 0.0050%. The upper limit thereof may be limited to 0.0030%, 0.0020%, 0.0010%, or 0.0003%. The lower limit of the Mg content does not need to be defined particularly, and the lower limit thereof is 0%.

[0049] The welded steel according to the embodiment may include the following alloy elements for the purpose of further improving the strength and the toughness of the steel itself, or as impurities from auxiliary raw material such as scrap, in addition to the above components.

[0050] Ca is mixed as an impurity in some cases and thus, the upper limit thereof may be limited to 0.0010%, 0.0005%, or 0.0003%.

[0051] Rare earth metal (REM) is mixed as impurities in some cases and thus, the upper limit thereof may be limited to 0.0010%, 0.0005%, or 0.0003%. Here, the REM is a general term of 17 elements including 15 lanthanoid elements and Y and Sc.

[0052] Sb deteriorates the toughness of the HAZ and thus, the upper limit of the Sb content may be 0.03%. In order to improve the toughness of the HAZ, the upper limit of the Sb content may be 0.01%, 0.005%, 0.003%, or 0.001%.

[0053] Since As and Sn deteriorate toughness of the HAZ, the upper limits of the As and Sn contents may be 0.02%. As necessary, the upper limits of the As and Sn contents may be 0.005%, 0.003%, or 0.001%. In addition, the lower limits of Ca, REM, Sb, As, and Sn do not need to be defined particularly and the lower limits are 0%.

[0054] In addition, to improve the strength and the toughness, each of Pb, Zr, Zn, and W content is set to 0.1% or less, 0.01% or 0.005% or less. The lower limits do not need to be defined particularly and are 0%.

[0055] Co is included as an impurity in Ni in some cases. Since Co deteriorates the toughness of the HAZ, the upper limit of the Co content may be 0.05% or 0.002%. The lower limit thereof does not need to be defined particularly, and the lower limit thereof is 0%.

[0056] Each of the elements is limited as described above and further, it is necessary that P_{CM} of the following Expression 4 that can be said to be total amount regulation is limited within an appropriate range. The following Expression 4 is a known expression as a weld cracking parameter (P_{CM}). Even when all the elements are within the limitation ranges, the hardenability is insufficient or excessive in a case that all elements are lower limits or all elements are upper limits. In the former case, an increase in thickness and strength cannot be attained and in the latter case, the hardness of the heat-affected zone and MA formation become excessive and thus, it is difficult to ensure toughness. In order to stably ensure the strength with the target thickness of the present invention and stably ensure the toughness of the heat-affected zone, it is necessary to set P_{CM} to 0.18% to 0.23%.

$$P_{CM} = [C] + [Si]/30 + [Mn]/20 + [Cu]/20 + [Ni]/60 + [Cr]/20 + [Mo]/15 + [V]/10 + 5[B] \ldots \text{Expression 4}$$

[0057] Here, each of the elements represents the amounts included in the steel by mass%.

[0058] Further, it has been found that it is important that the number of oxides having an equivalent circle diameter of 2 μm or more is 20 particles/mm^2 or less, and the number of Ti oxides included as transformation nuclei in the steel and having an equivalent circle diameter of 0.05 μm to 0.5 μm is 1.0×10^3 particles/mm^2 to 1.0×10^5 particles/mm^2 to satisfy the CTOD properties. When the number of oxides having an equivalent circles diameter of 2 μm or more exceeds 20 particles/mm^2, the oxides act as a starting point of fracture and the CTOD properties are deteriorated. In addition, when the number of Ti oxides having an equivalent circle diameter of 0.05 μm to 0.5 μm is less than 1.0×10^3 particles/mm^2, the number of Ti oxides as nuclei for forming intragranular transformation ferrite is insufficient and when the number of Ti oxides exceeds 1.0×10^5 particles/mm^2, the Ti oxides act as a starting point of fracture, and in both the cases, the CTOD properties are deteriorated.

[0059] It is also necessary to limit the production method to industrially produce a thick high strength steel plate with stability while limiting the components of the steel as described above.

[0060] Next, an example of a method of producing an ultrahigh tensile strength steel for welding will be described.

[0061] It is preferable that the steel of the present invention is produced industrially by a continuous casting method. The reason is that the solidification cooling rate of molten steel is high and a large amount of fine Ti oxides and Ti nitrides can be formed in a slab. In the method of producing the welded steel according to the embodiment, it is preferable that an average cooling rate at the center portion of the slab to 800°C from around a solidifying point is 5 °C/min or higher. The reason is to obtain oxides having an equivalent circle diameter of 2 μm or more of 20 particles/mm^2 or less and Ti oxides having an equivalent circle diameter of 0.05 μm to 0.5 μm of 1.0×10^3 particles/mm^2 to 1.0×10^5 particles/mm^2 in the steel. When the cooling rate of the slab is lower than 5 °C/min, fine oxides are hardly obtained and coarse oxides increase. On the other hand, even when the average cooling rate exceeds 50 °C/min, the number of fine Ti oxides does not significantly increase and the cost of production rather increases, and thus, the average cooling rate may be 50 °C/min or lower.

[0062] The average cooling rate at the center portion of the slab can be obtained by measuring the cooling rate of the surface of the slab and performing thermal conduction calculation. In addition, the average cooling rate can also be obtained by measuring a casting temperature and an amount of cooling water and performing thermal conduction calculation.

[0063] When the slab is rolled, the re-heating temperature thereof is preferably 1000°C to 1100°C. When the re-heating temperature exceeds 1100°C, the Ti oxides are coarsened and an effect of improving deterioration in toughness of the base metal or the toughness of the HAZ cannot be expected. In addition, at a re-heating temperature of lower than 1000°C, rolling reaction force increases and a rolling load increases, and thus, the productivity is impaired.

[0064] After the re-heating, production in TMCP is required. First, rolling is performed at a temperature of 950°C or higher under a cumulative reduction of 30% or more. In the rolling in a high temperature region, the grains of heated coarse austenite are sized and refined, and thus, the more the cumulative reduction, the more preferable it is. However, the rolling in a high temperature region is regulated by the thickness of the slab and the subsequent rolling conditions. It is difficult to grasp the rolled structure in a high temperature state, but in the factory or laboratory test of the inventors, when the cumulative reduction is 30% or more and the subsequent rolling-cooling conditions are within an appropriate range, it has been confirmed that the properties are stable.

[0065] Next, the rolling is performed under a cumulative reduction of 40% or more at a temperature of 720°C to 950°C and a total cumulative reduction of 60% or more, and the rolling is finished at a temperature of 700°C to 750°C. The temperature regions are mostly austenite non-recrystallization temperature regions. However, since thick material has temperature distribution in a thickness direction and has a high temperature in the vicinity of the thickness center portion, rolling may not be sufficiently performed in the non-recrystallization temperature region. Therefore, the temperature and the cumulative reduction are limited in two stages the in the present invention. The rolling under a cumulative reduction of 40% or more at a temperature of 720°C to 950°C is a minimum required rolling reduction in austenite non-recrystallization by a depth of about 1/4 of the thickness from the surface layers of the front and rear surfaces. Further, the reason for finishing the rolling with a total cumulative reduction of 60% or more at a temperature of 700°C to 750°C is that the rolling is applied to even to the thickness center portion in the austenite non-recrystallization temperature region to a degree that enables structure refinement. In the thickness center portion, a relatively small reduction in the austenite non-recrystallization temperature region is unavoidable, but the structure can be refined to a degree at which satisfactory a balance between strength and toughness can be ensured with a relatively low heating temperature and an appropriate reduction in a high temperature region limited in the present invention. In the rolling conditions deviated from the limitation ranges, it has been experimentally confirmed that the toughness of the thickness center portion is particularly deteriorated.

[0066] Further, as for cooling after the rolling, it is necessary to perform cooling to 280°C or lower by starting water cooling within 80 seconds after the rolling is finished. It is preferable that water cooling start rapidly after the rolling. However, it is unavoidable that a certain period of time is required for transportation from an end of a rolling mill to a cooling facility in large real production facilities. Even in this case, the precipitation of ferrite during air cooling until the cooling after the rolling is not preferable in terms of strength, and the ferrite is highly likely to be coarsened due to precipitation in the air cooling, which is not preferable in terms of toughness. Therefore, it is necessary to start water cooling within 80 seconds after the rolling is finished. The water cooling preferably starts within 60 seconds. Since the water cooling is necessarily performed until transformation is completely completed even at the thickness center portion in which a thermal conduction rate is controlled, cooling to 280°C or lower is necessary. Since an accelerated cooling effect at the thickness center portion of the thick material, which is targeted in the present invention, is obtained, it is preferable to perform cooling at a sprayed water density of about 1.2 m^3/m^2/min or more.

[0067] After the cooling, tempering has to be performed in a temperature range of 400°C to 550°C. By performing the tempering, the balance between strength and toughness of the base metal are improved and also can be stably controlled with high accuracy. Further, nonuniformity at the time of cooling is alleviated, and thus, an effect of releasing residual stress in the steel is obtained. Also, shape change caused by the nonuniformity and the residual stress at the time of cutting is suppressed. When the tempering is performed at a temperature of lower than 400°C, the effects are reduced and when the tempering is performed at a temperature of higher than 550°C, the strength is significantly reduced and it is difficult to ensure high strength that is targeted in the present invention.

[0068] Here, all the aforementioned temperatures are steel surface temperatures.

[0069] From the above, in the method of producing the ultrahigh tensile strength steel for welding having excellent weldability and toughness of the heat-affected zone, for example, a steel piece or a cast piece having the steel components described (1) is heated at a temperature of 1000°C to 1100°C, rolling is finished such that the cumulative reduction is 30% or more at a temperature of 950°C or higher, the cumulative reduction is 40% or more at a temperature of 720°C to 950°C, and the cumulative reduction is 60% or more at a temperature of 700°C to 750°C, water cooling is performed within 80 seconds after the rolling is finished to cool the steel to 280°C or lower, and then, further tempering is performed in a temperature range of 400°C to 550°C.

[Examples]

[0070] Hereinafter, the present invention will be described based on Examples and Comparative examples.

[0071] Using a converter, continuous casting, and rolling process, a thick steel plate having various kinds of steel components was produced, and the toughness of the base metal and the heat-affected zone was evaluated.

[0072] The welding was performed by the submerged arc welding method that is generally used as test welding and multilayer welding was performed with a weld heat input of 4.5 kJ/mm at a K groove so that the weld fusion line (FL) became vertical. As the toughness evaluation of the heat-affected zone, a CTOD test was performed according to American Petroleum Institute (API) standard RP 2Z and British Standard (BS) 7448. Notches were made on the fusion line that is referred to as coarse grain HAZ (CGHAZ) and six pieces were tested at a test temperature of -10°C on each.

[0073] In Tables 1-1 to 1-4, the chemical components of the steels are shown and in Tables 2-1 to 2-4, the manufacturing condition, the number of oxides in the steels, the properties of the base metal, the toughness of the heat-affected zone (CTOD properties) are shown. In the steel plates produced in the present invention (invention steels: steel component Nos. 1 to 15 and 29 to 51, and Example Nos. A1 to L2), the yield strength (YS) was 526 MPa to 611 MPa at a depth position of 1/4 of the steel plate and the yield strength was 516 MPa to 594 MPa at a depth position of 1/2 of the steel plate, and the tensile strength (TS) was 616 MPa to 680 MPa at a depth position of 1/4 of the steel plate and the tensile strength was 604 MPa to 656 MPa at a depth position of 1/2 of the steel plate. In the fracture transition (vTrs) test results of the toughness of the base metal, the fracture transition temperatures were -48°C to -81°C at a depth position of 1/4 of the steel plate and the fracture transition temperatures were -40°C to -68°C at a depth position of 1/2 of the steel plate, and the lowest CTOD value at -10°C was 0.29 mm to 0.94 mm, and thus, satisfactory fracture toughness was exhibited. Further, satisfactory weldability was exhibited by the P_{CM} values and the CTOD properties of the invention steels.

[0074] On the other hand, in the steel plates of the Comparative examples deviated from the limitation ranges of the present invention (comparative steels: steel component Nos. 16 to 28 and 52 to 62, and Comparative example Nos. a to x), the strength of the base metal was decreased, the toughness of the base metal was deteriorated, or the toughness of the heat-affected zone was deteriorated.

[0075] That is, the steel components in Comparative examples a to c, Comparative examples e to o, and Comparative examples q to v were out of the range of the present invention and the above-described mechanical properties were not satisfied. Particularly, since Comparative example f with the steel component No. 21 did not satisfy Ni/Cu > 2.0, cracking occurred at the time of hot rolling and thus the production was difficult. Further, Comparative examples d, w, and x whose steel components are within the range of the present invention but the FB or P_{CM} values are out of the range of the present invention did not satisfy FB ≥ 0.0003%, or the P_{CM} value was not within a range of 0.18% to 0.23%, and thus, the strength of the base metal was decreased or increased, the toughness of the base metal was deteriorated, or the toughness of the heat-affected zone was deteriorated.

[Table 1-1]

	Steel	C	Mn	Cu	Ni	Nb	Mo	Ti	B	N	O	Si	P	S	Al	Cr	V	Mg
		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
Example	1	0.016	2.19	0.67	1.78	0.009	0.23	0.009	0.0017	0.0038	0.0026	0.14	0.006	0.002	0.002	0.01	0.001	0.0000
	2	0.018	2.15	0.61	1.65	0.013	0.20	0.012	0.0012	0.0042	0.0025	0.12	0.007	0.003	0.002	0.01	0.002	0.0001
	3	0.019	2.12	0.59	1.71	0.012	0.16	0.010	0.0015	0.0037	0.0021	0.11	0.005	0.001	0.001	0.02	0.000	0.0000
	4	0.021	2.01	0.65	1.52	0.010	0.15	0.012	0.0011	0.0036	0.0032	0.09	0.006	0.003	0.002	0.00	0.000	0.0000
	5	0.024	1.98	0.47	1.50	0.011	0.18	0.008	0.0008	0.0029	0.0017	0.12	0.006	0.003	0.003	0.01	0.002	0.0001
	6	0.027	2.02	0.50	1.49	0.008	0.09	0.012	0.0012	0.0043	0.0021	0.08	0.005	0.002	0.002	0.01	0.001	0.0001
	7	0.028	1.97	0.45	1.53	0.007	0.12	0.013	0.0011	0.0039	0.0024	0.05	0.007	0.001	0.002	0.00	0.000	0.0002
	8	0.030	2.03	0.51	1.20	0.011	0.10	0.008	0.0016	0.0030	0.0027	0.09	0.006	0.002	0.001	0.01	0.001	0.0000
	9	0.033	2.00	0.55	1.11	0.012	0.10	0.009	0.0013	0.0034	0.0018	0.10	0.005	0.001	0.001	0.02	0.000	0.0000
	10	0.034	1.89	0.56	1.19	0.009	0.06	0.008	0.0012	0.0029	0.0019	0.11	0.006	0.002	0.001	0.01	0.000	0.0001
	11	0.037	1.92	0.42	1.03	0.012	0.15	0.014	0.0018	0.0050	0.0023	0.07	0.005	0.003	0.001	0.00	0.000	0.0000
	12	0.039	1.90	0.56	1.22	0.011	0.14	0.013	0.0012	0.0044	0.0025	0.08	0.005	0.002	0.002	0.00	0.001	0.0001
	13	0.040	1.85	0.57	1.20	0.011	0.12	0.011	0.0009	0.0039	0.0018	0.09	0.006	0.002	0.002	0.01	0.001	0.0001
	14	0.042	1.83	0.60	1.23	0.006	0.10	0.006	0.0018	0.0024	0.0031	0.10	0.007	0.001	0.002	0.00	0.001	0.0002
	15	0.044	1.82	0.42	0.85	0.009	0.09	0.010	0.0014	0.0035	0.0029	0.10	0.006	0.002	0.002	0.02	0.002	0.0000
Comparative example	16	0.012	1.92	0.50	1.80	0.010	0.22	0.011	0.0010	0.0036	0.0027	0.09	0.007	0.003	0.002	0.01	0.002	0.0002
	17	0.048	1.84	0.51	1.09	0.009	0.14	0.010	0.0010	0.0034	0.0021	0.09	0.006	0.002	0.002	0.01	0.002	0.0001
	18	0.034	1.65	0.50	1.04	0.010	0.13	0.010	0.0009	0.0035	0.0024	0.12	0.006	0.003	0.001	0.00	0.001	0.0000
	19	0.030	1.95	0.55	1.19	0.010	0.16	0.011	0.0010	0.0039	0.0020	0.28	0.006	0.002	0.001	0.02	0.002	0.0000
	20	0.035	1.99	0.81	1.64	0.008	0.18	0.012	0.0011	0.0041	0.0025	0.11	0.005	0.003	0.002	0.01	0.002	0.0001
	21	0.029	1.90	0.65	0.70	0.010	0.15	0.010	0.0009	0.0034	0.0023	0.13	0.006	0.002	0.002	0.01	0.001	0.0001
	22	0.034	1.98	0.51	1.20	0.001	0.09	0.010	0.0011	0.0033	0.0026	0.10	0.007	0.003	0.001	0.00	0.000	0.0000
	23	0.034	1.98	0.51	1.20	0.020	0.09	0.010	0.0011	0.0033	0.0026	0.10	0.007	0.003	0.002	0.01	0.000	0.0000
	24	0.031	2.01	0.48	1.02	0.012	0.34	0.009	0.0009	0.0030	0.0025	0.11	0.006	0.002	0.001	0.00	0.001	0.0001
	25	0.040	1.99	0.45	0.99	0.009	0.15	0.022	0.0014	0.0029	0.0028	0.12	0.007	0.003	0.002	0.00	0.000	0.0001
	26	0.039	2.00	0.46	0.98	0.009	0.18	0.011	0.0002	0.0032	0.0024	0.09	0.006	0.002	0.002	0.01	0.001	0.0002
	27	0.036	1.89	0.48	1.00	0.010	0.14	0.010	0.0007	0.0062	0.0022	0.13	0.007	0.003	0.002	0.02	0.001	0.0000
	28	0.037	2.02	0.59	1.35	0.011	0.09	0.010	0.0011	0.0037	0.0022	0.09	0.007	0.002	0.007	0.02	0.002	0.0001

[Table 1-2]

Steel		Ni/Cu	N-Ti/3.4	FB	P_{CM}	Bp
		[-]	[%]	[%]	[%]	[%]
Example	1	2.66	0.0012	0.0004	0.218	0.129
	2	2.70	0.0007	0.0004	0.208	0.124
	3	2.90	0.0008	0.0003	0.206	0.093
	4	2.34	0.0001	0.0004	0.198	0.117
	5	3.19	0.0005	0.0003	0.192	0.095
	6	2.98	0.0008	0.0004	0.193	0.127
	7	3.40	0.0001	0.0007	0.190	0.223
	8	2.35	0.0006	0.0003	0.195	0.096
	9	2.02	0.0008	0.0003	0.197	0.097
	10	2.13	0.0005	0.0003	0.191	0.097
	11	2.45	0.0009	0.0004	0.193	0.131
	12	2.18	0.0006	0.0004	0.200	0.129
	13	2.11	0.0007	0.0004	0.197	0.132
	14	2.05	0.0006	0.0007	0.203	0.232
	15	2.02	0.0006	0.0005	0.188	0.166
Comparative example	16	3.60	0.0004	0.0003	0.186	0.083
	17	2.14	0.0005	0.0005	0.202	0.159
	18	2.08	0.0006	0.0000	0.176	0.000
	19	2.16	0.0007	0.0000	0.201	-0.014
	20	2.02	0.0006	0.0003	0.224	0.098
	21	1.08	0.0005	0.0003	0.188	0.090
	22	2.35	0.0004	0.0000	0.193	0.009
	23	2.35	0.0004	0.0004	0.194	0.138
	24	2.13	0.0004	0.0000	0.203	0.000
	25	2.20	-0.0036	0.0014	0.200	0.461
	26	2.13	0.0000	0.0000	0.195	0.000
	27	2.08	0.0033	0.0000	0.189	0.000
	28	2.29	0.0008	0.0023	0.206	0.746

[Table 1-3]

Steel		C	Mn	Cu	Ni	Nb	Mo	Ti	B	N	O	Si	P	S	Al	Cr	V	Mg
		[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
Example	29	0.037	1.90	0.60	1.25	0.008	0.13	0.009	0.0009	0.0029	0.0024	0.10	0.006	0.002	0.002	0.06	0.001	0.0001
	30	0.036	1.82	0.56	1.21	0.009	0.21	0.012	0.0011	0.0034	0.0028	0.12	0.007	0.002	0.002	0.14	0.000	0.0001
	31	0.018	1.97	0.55	1.18	0.007	0.10	0.010	0.0013	0.0037	0.0027	0.12	0.007	0.002	0.003	0.27	0.001	0.0002
	32	0.039	1.95	0.50	1.06	0.008	0.15	0.010	0.0015	0.0032	0.0029	0.11	0.005	0.002	0.001	0.01	0.009	0.0000
	33	0.036	2.01	0.52	1.10	0.010	0.13	0.008	0.0012	0.0035	0.0026	0.09	0.007	0.003	0.003	0.02	0.023	0.0001
	34	0.019	1.97	0.51	1.04	0.009	0.12	0.013	0.0009	0.0035	0.0026	0.06	0.007	0.003	0.003	0.01	0.045	0.0000
	35	0.035	2.00	0.48	1.01	0.008	0.12	0.012	0.0011	0.0040	0.0024	0.10	0.006	0.001	0.002	0.01	0.001	0.0008
	36	0.040	2.02	0.51	1.09	0.008	0.09	0.010	0.0013	0.0038	0.0024	0.11	0.006	0.003	0.002	0.02	0.000	0.0016
	37	0.021	1.99	0.62	1.44	0.008	0.18	0.010	0.0010	0.0034	0.0022	0.08	0.006	0.002	0.002	0.01	0.001	0.0024
	38	0.034	2.05	0.42	0.85	0.009	0.15	0.011	0.0008	0.0031	0.0024	0.09	0.006	0.002	0.003	0.13	0.029	0.0001
	39	0.017	2.03	0.46	0.97	0.010	0.15	0.012	0.0007	0.0033	0.0021	0.11	0.007	0.001	0.002	0.18	0.026	0.0002
	40	0.026	2.10	0.43	1.00	0.009	0.14	0.009	0.0013	0.0031	0.0027	0.10	0.006	0.001	0.003	0.22	0.031	0.0001
	41	0.036	2.00	0.49	1.02	0.009	0.11	0.008	0.0012	0.0029	0.0026	0.08	0.006	0.002	0.003	0.11	0.000	0.0008
	42	0.033	1.99	0.51	1.10	0.008	0.09	0.013	0.0009	0.0038	0.0020	0.07	0.006	0.003	0.002	0.12	0.001	0.0016
	43	0.028	2.02	0.50	1.08	0.009	0.10	0.011	0.0011	0.0034	0.0023	0.06	0.007	0.002	0.001	0.21	0.000	0.0024
	44	0.042	1.86	0.52	1.21	0.010	0.10	0.012	0.0009	0.0036	0.0023	0.12	0.007	0.002	0.002	0.02	0.019	0.0012
	45	0.040	1.85	0.53	1.22	0.008	0.10	0.012	0.0010	0.0037	0.0024	0.11	0.007	0.002	0.002	0.01	0.025	0.0018
	46	0.036	1.89	0.52	1.18	0.009	0.12	0.010	0.0009	0.0030	0.0028	0.11	0.007	0.003	0.003	0.01	0.041	0.0009
	47	0.042	1.92	0.46	0.99	0.008	0.15	0.010	0.0012	0.0035	0.0030	0.09	0.007	0.003	0.003	0.18	0.028	0.0011
	48	0.043	1.95	0.46	0.98	0.010	0.18	0.009	0.0014	0.0032	0.0021	0.10	0.006	0.002	0.002	0.13	0.035	0.0015
	49	0.036	1.91	0.45	1.01	0.009	0.19	0.009	0.0012	0.0033	0.0025	0.07	0.006	0.003	0.002	0.09	0.019	0.0013
	50	0.029	1.84	0.51	1.09	0.009	0.14	0.010	0.0015	0.0034	0.0021	0.09	0.006	0.002	0.002	0.01	0.002	0.0001
	51	0.040	1.98	0.61	1.43	0.010	0.09	0.008	0.0013	0.0027	0.0024	0.11	0.006	0.002	0.001	0.01	0.001	0.0000
Comparative example	52	0.039	2.36	0.48	1.04	0.011	0.15	0.010	0.0010	0.0036	0.0022	0.09	0.006	0.003	0.002	0.01	0.001	0.0001
	53	0.042	2.01	0.28	0.82	0.012	0.16	0.010	0.0009	0.0032	0.0026	0.11	0.007	0.003	0.002	0.02	0.001	0.0001
	54	0.027	1.95	0.59	2.01	0.010	0.11	0.011	0.0012	0.0039	0.0021	0.08	0.006	0.002	0.002	0.01	0.000	0.0001
	55	0.033	1.94	0.51	1.18	0.011	0.02	0.012	0.0007	0.0031	0.0019	0.10	0.007	0.002	0.003	0.01	0.000	0.0001
	56	0.038	2.10	0.50	1.21	0.013	0.12	0.003	0.0014	0.0033	0.0025	0.10	0.007	0.002	0.003	0.01	0.001	0.0000
	57	0.037	2.08	0.52	1.10	0.008	0.09	0.008	0.0025	0.0028	0.0028	0.13	0.006	0.003	0.003	0.01	0.000	0.0002
	58	0.025	1.99	0.47	1.02	0.011	0.10	0.011	0.0008	0.0017	0.0023	0.14	0.006	0.002	0.002	0.02	0.002	0.0000
	59	0.026	1.92	0.55	1.23	0.009	0.11	0.009	0.0012	0.0031	0.0040	0.11	0.006	0.003	0.003	0.01	0.000	0.0001
	60	0.040	1.84	0.60	1.32	0.009	0.13	0.012	0.0008	0.0036	0.0012	0.12	0.007	0.002	0.003	0.01	0.000	0.0001
	61	0.042	2.17	0.67	1.74	0.009	0.21	0.012	0.0007	0.0036	0.0026	0.12	0.007	0.002	0.003	0.09	0.000	0.0001
	62	0.043	1.92	0.50	1.04	0.010	0.13	0.009	0.0010	0.0028	0.0024	0.12	0.006	0.003	0.001	0.11	0.001	0.0000

[Table 1-4]

Steel		Ni/Cu	N-Ti/3.4	FB	P_{CM}	Bp
		[−]	[%]	[%]	[%]	[%]
Example	29	2.08	0.000	0.0004	0.202	0.131
	30	2.16	0.000	0.0007	0.206	0.230
	31	2.15	0.001	0.0007	0.194	0.217
	32	2.12	0.000	0.0003	0.202	0.099
	33	2.12	0.001	0.0003	0.202	0.105
	34	2.04	0.000	0.0009	0.180	0.280
	35	2.10	0.000	0.0004	0.193	0.137
	36	2.14	0.001	0.0004	0.202	0.132
	37	2.32	0.000	0.0005	0.196	0.156
	38	2.02	0.000	0.0008	0.198	0.259
	39	2.11	0.000	0.0007	0.186	0.215
	40	2.33	0.000	0.0009	0.202	0.285
	41	2.08	0.001	0.0007	0.199	0.228
	42	2.16	0.000	0.0008	0.195	0.252
	43	2.16	0.000	0.0003	0.197	0.096
	44	2.33	0.000	0.0006	0.199	0.191
	45	2.30	0.000	0.0005	0.198	0.165
	46	2.27	0.000	0.0007	0.197	0.228
	47	2.15	0.001	0.0006	0.208	0.196
	48	2.13	0.001	0.0008	0.212	0.267
	49	2.24	0.001	0.0004	0.198	0.130
	50	2.14	0.000	0.0010	0.185	0.311
	51	2.34	0.000	0.0003	0.210	0.099
Comparative example	52	2.17	0.001	0.0003	0.217	0.099
	53	2.93	0.000	0.0003	0.190	0.099
	54	3.41	0.001	0.0005	0.204	0.159
	55	2.31	0.000	0.0007	0.184	0.226
	56	2.42	0.002	0.0000	0.207	0.000
	57	2.12	0.000	0.0021	0.209	0.686
	58	2.17	-0.002	0.0008	0.182	0.253
	59	2.24	0.000	0.0003	0.188	0.095
	60	2.20	0.000	0.0007	0.201	0.231
	61	2.60	0.000	0.0006	0.239	0.199
	62	2.08	0.000	0.0002	0.205	0.066

[Table 2-1]

Steel		Component	Average cooling rate at center portion of cast slab (°C/min)	Heating temperature (°C)	Cumulative reduction at 950°C or higher (%)	Cumulative reduction at 720°C to 950°C (%)	Total cumulative reduction (%)	Finish rolling temperature (°C)	Time from finish of rolling to start of water cooling (sec)	Cooling stop temperature (°C)	Tempering temperature (°C)	Thickness (mm)
Example	A1	1	11	1080	50	58	78	710	50	190	540	50
	B1	2	12	1100	38	60	75	730	50	200	520	60
	C1	3	11	1050	38	50	69	730	60	220	480	75
	D1	4	10	1050	33	50	67	730	50	240	500	80
	E1	5	12	1100	40	44	67	745	50	260	410	100
	F1	6	12	1050	40	50	70	740	60	250	450	90
	G1	7	13	1000	33	50	67	730	60	250	450	80
	H1	8	11	1000	38	50	69	730	60	230	430	75
	I1	9	12	1000	38	57	73	720	50	220	500	65
	J1	10	13	1100	42	54	73	730	45	230	420	80
	K1	11	12	1100	33	50	67	730	45	230	450	80
	L1	12	12	1040	38	50	69	720	50	220	450	75
	M1	13	13	1040	40	44	67	740	60	260	500	100
	N1	14	14	1100	33	50	67	730	50	250	470	80
	O1	15	12	1080	38	50	69	730	50	240	470	75
Comparative example	a	16	13	1060	38	50	69	740	50	230	500	75
	b	17	12	1060	38	50	69	740	50	230	500	75
	c	18	12	1060	38	50	69	740	60	230	500	75
	d	19	13	1100	38	50	69	730	60	220	500	75
	e	20	13	1100	38	50	69	730	60	240	500	75
	f	21	13	1100	33	50	67	740	50	240	450	80
	g	22	12	1100	33	50	67	740	50	230	450	80
	h	23	11	1100	33	50	67	740	50	240	450	80
	i	24	12	1100	38	60	75	730	50	230	520	60
	j	25	12	1050	38	60	75	730	50	220	520	60
	k	26	12	1050	38	60	75	730	50	210	520	60
	l	27	13	1050	38	60	75	730	50	210	520	60
	m	28	12	1050	38	60	75	730	50	200	520	60

[Table 2-2]

Steel		Component	Number of oxides having equivalent circle diameter of 2 µm or more (particles/mm²)	Number of Ti oxides having equivalent circle diameter of 0.05 µm to 0.5 µm (10³particles/mm²)	Depth position of 1/4 of steel plate			Depth position of 1/2 of steel plate			Heat affected zone
					YS (MPa)	TS (MPa)	vTrs (°C)	YS (MPa)	TS (MPa)	vTrs (°C)	Lowest CTOD value (mm)
Example	A1	1	11	9. 1	605	668	-78	587	647	-46	0. 93
	B1	2	13	8. 8	598	663	-75	578	649	-42	0. 86
	C1	3	10	12. 3	576	670	-74	552	656	-45	0. 91
	D1	4	15	10. 4	588	662	-70	561	651	-40	0. 92
	E1	5	12	8. 0	572	651	-75	554	624	-42	0. 94
	F1	6	12	14. 2	539	655	-67	518	636	-43	0. 87
	G1	7	13	11. 3	544	660	-63	522	637	-44	0. 89
	H1	8	9	10. 2	563	652	-68	546	641	-41	0. 85
	I1	9	12	9. 7	572	663	-72	559	645	-42	0. 94
	J1	10	11	9. 4	561	645	-70	542	629	-45	0. 88
	K1	11	10	8. 6	574	641	-65	555	628	-44	0. 84
	L1	12	13	10. 9	569	648	-72	547	631	-42	0. 91
	M1	13	9	12. 4	536	623	-67	522	609	-46	0. 91
	N1	14	12	13. 0	526	654	-68	518	632	-41	0. 86
	01	15	10	11. 2	531	646	-64	516	629	-43	0. 88
Comparative example	a	16	13	8. 7	468	531	-75	442	519	-47	0. 87
	b	17	12	9. 1	712	746	-12	688	721	-1	0. 11
	c	18	12	8. 4	473	553	-42	452	531	-9	0. 79
	d	19	10	7. 8	591	643	-21	564	619	-3	0. 08
	e	20	11	10. 4	704	721	-14	694	712	-1	0. 13
	f	21	13	11. 2	523	609	-16	509	592	-7	0. 13
	g	22	9	11. 0	455	534	-7	436	521	2	0. 86
	h	23	11	9. 3	551	634	-38	534	618	-22	0. 09
	i	24	13	8. 7	688	736	-27	671	714	-16	0. 14
	j	25	9	10. 1	566	641	-54	545	632	-34	0. 08
	k	26	10	9. 6	471	574	-39	458	559	-24	0. 21
	l	27	10	12. 8	457	536	-25	436	521	-18	0. 67
	m	28	12	7. 9	574	656	-23	554	642	-13	0. 07

[Table 2-3]

	Steel	Component	Average cooling rate at center portion of cast slab (°C/min)	Heating temperature (°C)	Cumulative reduction at 950°C or higher (%)	Cumulative reduction at 720°C to 950°C (%)	Total cumulative reduction (%)	Finish rolling temperature (°C)	Time from finish of rolling to start of water cooling (sec)	Cooling stop temperature (°C)	Tempering temperature (°C)	Thickness (mm)
Example	P1	29	14	1080	38	50	69	750	60	240	500	75
	Q1	30	14	1080	38	50	69	750	60	260	500	75
	R1	31	12	1050	38	50	69	740	50	250	470	75
	S1	32	11	1050	38	50	69	750	60	260	470	75
	T1	33	12	1050	38	50	69	730	50	230	470	75
	U1	34	12	1080	38	50	69	740	50	240	520	75
	V1	35	13	1080	38	50	69	740	60	230	520	75
	W1	36	12	1050	38	50	69	740	60	250	520	75
	X1	37	11	1050	38	50	69	750	60	260	520	75
	Y1	38	12	1050	38	50	69	730	50	230	520	75
	Z1	39	13	1080	38	50	69	750	60	240	500	75
	A2	40	14	1080	38	50	69	750	60	260	500	75
	B2	41	12	1050	38	50	69	740	50	250	500	75
	C2	42	11	1050	38	50	69	750	60	260	500	75
	D2	43	12	1050	38	50	69	730	50	230	500	75
	E2	44	12	1080	38	50	69	750	60	250	500	75
	F2	45	12	1080	38	50	69	740	60	250	500	75
	G2	46	12	1050	38	50	69	740	50	250	520	75
	H2	47	11	1050	38	50	69	750	60	260	520	75
	I2	48	12	1050	38	50	69	730	50	230	520	75
	J2	49	14	1050	38	50	69	750	60	250	520	75
	K2	50	11	1050	38	50	69	750	60	260	500	75
	L2	51	12	1050	50	67	83	760	50	240	560	40
Comparative example	n	52	11	1050	38	50	69	740	50	250	500	75
	o	53	12	1050	38	50	69	750	60	260	500	75
	p	54	12	1050	38	50	69	730	50	230	500	75
	q	55	11	1080	38	50	69	740	60	260	500	75
	r	56	11	1080	38	50	69	750	60	240	500	75
	s	57	14	1050	38	50	69	740	50	250	500	75
	t	58	12	1050	38	50	69	750	60	260	500	75
	u	59	12	1050	38	50	69	730	50	230	500	75
	v	60	11	1080	38	50	69	740	60	260	500	75
	w	61	11	1080	38	50	69	750	60	270	500	75
	x	62	12	1050	38	50	69	730	50	230	500	75

[Table 2-4]

Steel		Component	Number of oxides having equivalent circle diameter of 2 µm or more (particles/mm^2)	Number of Ti oxides having equivalent circle diameter of 0.05 µm to 0.5 µm (10^3particles/mm^2)	Depth position of 1/4 of steel plate			Depth position of 1/2 of steel plate			Heat affected zone
					YS (MPa)	TS (MPa)	vTrs (°C)	YS (MPa)	TS (MPa)	vTrs (°C)	Lowest CTOD value (mm)
Example	P1	29	12	11.2	576	643	-52	548	621	-44	0.82
	Q1	30	9	10.7	582	645	-60	551	626	-52	0.91
	R1	31	11	9.0	563	628	-58	534	606	-50	0.85
	S1	32	12	10.3	580	642	-56	561	622	-48	0.84
	T1	33	10	8.6	567	630	-63	540	614	-55	0.90
	U1	34	9	10.1	584	647	-48	556	618	-42	0.78
	V1	35	11	9.9	561	623	-50	534	610	-47	0.81
	W1	36	11	9.0	588	653	-55	560	633	-49	0.76
	X1	37	12	10.3	580	644	-63	552	627	-54	0.83
	Y1	38	10	8.8	573	637	-61	546	607	-52	0.77
	Z1	39	12	13.8	576	640	-69	549	610	-58	0.92
	A2	40	12	12.9	574	645	-64	552	620	-50	0.75
	B2	41	11	9.0	596	655	-70	573	637	-63	0.84
	C2	42	12	10.3	589	669	-61	566	629	-54	0.82
	D2	43	10	9.0	553	628	-56	532	604	-47	0.85
	E2	44	9	9.9	550	625	-57	529	606	-43	0.81
	F2	45	13	9.7	566	651	-60	544	611	-45	0.78
	G2	46	11	9.0	575	639	-62	553	617	-47	0.86
	H2	47	12	10.7	592	680	-68	569	639	-50	0.91
	I2	48	10	8.6	545	616	-54	524	605	-46	0.88
	J2	49	12	10.6	577	647	-59	555	618	-48	0.82
	K2	50	12	10.3	596	670	-61	574	638	-51	0.29
	L2	51	12	9.6	611	672	-81	594	651	-68	0.94
Comparative example	n	52	11	9.0	564	633	-57	533	606	-24	0.19
	o	53	12	10.4	540	598	-52	517	576	-32	0.23
	p	54	10	8.9	571	642	-84	552	620	-72	0.94
	q	55	13	14.0	548	601	-48	514	588	-36	0.22
	r	56	12	12.1	478	531	-37	452	513	-32	0.11
	s	57	11	9.0	703	781	-36	677	752	-26	0.14
	t	58	12	10.6	555	618	-74	534	607	-65	0.12
	u	59	10	8.6	532	607	-38	502	584	-29	0.07
	v	60	12	11.8	582	654	-69	560	629	-53	0.16
	w	61	11	13.2	701	818	-38	674	775	-26	0.09
	x	62	10	8.8	481	528	-75	462	504	-54	0.21

[Industrial Applicability]

[0076] According to the present invention, it is possible to provide the ultrahigh tensile strength steel having excellent weldability and toughness of the heat-affected zone at a low cost and also possible to further increase safety while the size of a welded structure such as an offshore structure can be increased.

Claims

1. A steel plate comprising, as a chemical composition, by mass%,

C: 0.015% to 0.045%,
Mn: 1.80% to 2.20%,
Cu: 0.40% to 0.70%,
Ni: 0.80% to 1.80%,
Nb: 0.005% to 0.015%,
Mo: 0.05% to 0.25%,
Ti: 0.005% to 0.015%,
B: 0.0004% to 0.0020%,
N: 0.0020% to 0.0060%,
O: 0.0015% to 0.0035%,
Si: 0% to 0.40%,
P: 0.008% or less,
S: 0.005% or less,
Al: 0% to 0.004%,
Cr: 0% to 0.30%,
V: 0% to 0.06%,
Mg: 0% to 0.0050%, and
a balance consisting of Fe and unavoidable impurities,
wherein a value expressed by a following Expression 1 is more than 2.0,
a value expressed by a following Expression 2 is 0% or more,
FB expressed by a following Expression 3 is 0.0003% or more,
a P_{CM} value which is a weld cracking parameter expressed by a following Expression 4 is 0.18% to 0.23%, and
a number of oxide grains having an equivalent circle diameter of 2 μm or more is 20 particles/mm^2 or less and a number of Ti oxides having an equivalent circle diameter of 0.05 μm to 0.5 μm is 1.0×10^3 particles/mm^2 to 1.0×10^5 particles/mm^2 at a thickness center portion of a cross section in a thickness direction,

$$[Ni]/[Cu] \text{ ... Expression 1,}$$

$$[N]-[Ti]/3.4 \text{ ... Expression 2,}$$

$$FB = [B] - 0.77 \times ([N] - 0.29 \times ([Ti] - 2 \times ([O] - 0.89 \times [Al]))) \text{ ... Expression 3,}$$

$$P_{CM} = [C] + [Si]/30 + [Mn]/20 + [Cu]/20 + [Ni]/60 + [Cr]/20 + [Mo]/15 + [V]/10 + 5[B] \text{ ... Expression 4,}$$

here, [C], [Si], [Mn], [Cu], [Ni], [Cr], [Mo], [V], [Ti], [B], [N], [O], and [Al] represent respectively C, Si, Mn, Cu, Ni, Cr, Mo, V, Ti, B, N, O, and Al contents by mass%,
however, when the term of ([O] - 0.89 × [Al]) in the Expression 3 is 0 or less, the term of ([O] - 0.89 × [Al]) in the Expression 3 is set to 0 to calculate the FB,
also, when the term of ([Ti] - 2 × ([O] - 0.89 × [Al])) in the Expression 3 is 0 or less, the term of ([Ti] - 2 × ([O] - 0.89 × [Al])) in the Expression 3 is set to 0 to calculate the FB,
further, when the term of ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) in the Expression 3 is 0 or less, the term of ([N] - 0.29 × ([Ti] - 2 × ([O] - 0.89 × [Al]))) in the Expression 3 is set to 0 to calculate the FB, and

still further, when FB ≤ 0, FB = 0.

2. The steel plate according to Claim 1, wherein a Bp expressed by a following Expression 5 is 0.09% to 0.30%.

$$Bp = (884 \times [C] \times (1 - 0.3 \times [C]^2) + 294) \times FB \text{ ... Expression 5}$$

3. The steel plate according to Claim 1 or 2, further comprising, as the chemical composition, by mass%, Si: limited to 0.15% or less.

4. The steel plate according to any one of Claims 1 to 3, further comprising, as the chemical composition, by mass%, Mg: limited to less than 0.0003%.

5. The steel plate according to any one of Claims 1 to 4, wherein a thickness is 50 mm or more and 100 mm or less, a tensile strength is 600 MPa or more and 700 MPa or less, and a yield strength is 500 MPa or more and 690 MPa or less.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/066349

A. CLASSIFICATION OF SUBJECT MATTER
C22C38/00(2006.01)i, *C22C38/58*(2006.01)i, *B22D11/22*(2006.01)n, *C21D8/02*(2006.01)n

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)
C22C38/00, C22C38/58, B22D11/22, C21D8/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2013/077022 A1 (Nippon Steel & Sumitomo Metal Corp.), 30 May 2013 (30.05.2013), claims 1 to 3; paragraphs [0043] to [0045] & JP 5201301 B	1-5
A	JP 2004-100037 A (Sumitomo Metal Industries, Ltd.), 02 April 2004 (02.04.2004), claims 1 to 4; paragraph [0041] (Family: none)	1-5
A	JP 2006-124759 A (Kobe Steel, Ltd.), 18 May 2006 (18.05.2006), claims 1 to 4 & KR 10-2006-0049390 A & CN 1766148 A	1-5

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

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Date of the actual completion of the international search	Date of mailing of the international search report
20 August, 2013 (20.08.13)	27 August, 2013 (27.08.13)

Name and mailing address of the ISA/	Authorized officer
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Patent documents cited in the description

- JP 2011001625 A **[0009]**