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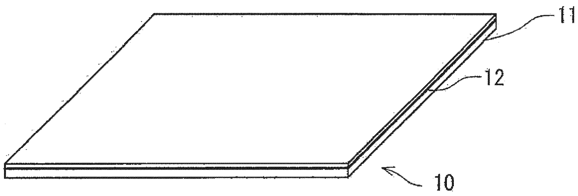
(54) BASE MATERIAL FOR CLAD STEEL, CLAD STEEL, AND METHOD FOR MANUFACTURING CLAD STEEL

(57) A base metal for clad steel contains: in terms of mass%, C: 0.04% to 0.10%, Si: 0.10% to 0.30%, Mn: 1.30% to 1.60%, P: 0.015% or less, S: 0.005% or less, Ni: 0.10% to 0.50%, Cr: 0.10% or less, Cu: 0.05% or less, Mo: 0.05% to 0.40%, V: 0.02% to 0.06%, Nb: 0.03% or less, Ti: 0.005% to 0.025%, Al: 0.020% to 0.050%, N: 0.0030% to 0.0100%, and the balance being Fe and unavoidable impurities. In the composition, a carbon equivalent Ceq according to the following formula (1) Ceq = C + Mn/6 + (Ni + Cu)/15 + (Cr + Mo + V)/5 (mass%) is 0.400 or less, and a yield ratio Y.R. according to the following formula (2) Y.R. = Y.S. (MPa; 0.5% Under load)/T.S. (MPa) is less than 0.80.

Figure



EP 3 943 621 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a base metal for clad steel used for a clad material, a clad steel including the base metal for clad steel, and a method for producing the same.

BACKGROUND ART

[0002] Since natural gas has less air pollution than petroleum energy, a demand of natural gas as clean energy is expected to increase further in the future, and a construction plan for natural gas pipelines is being greatly accelerated as an international economic policy. In the mining of natural gas, in many cases, gases having strong corrosiveness such as hydrogen sulfide, carbon dioxide gas, and chlorine gas are contained in addition to the target gas, and as a steel pipe that can withstand use in a corrosive gas environment, a clad pipe is used which is formed of a clad steel sheet obtained by joining stainless steel having excellent corrosion resistance and low-alloy steel having high strength and high toughness.

[0003] In recent years, as an efficient method of laying a pipeline, there is often adopted a method called reeling, in which a line pipe that is girth-welded and joined on the ground is once wound up on a reel on a ship and then laid while bending back at a predetermined point on the ocean. When the pipeline is laid in this method, a considerable amount of plastic deformation is applied to the clad pipe base metal, and thus a base metal having a low yield ratio is required from the viewpoint of improving safety.

[0004] Traditionally, Patent Literature 1 discloses a steel sheet which consists of martensite-austenite constituent with an area fraction of 2% to 15% and bainite structure of a base metal of a clad steel sheet by accelerated cooling from a temperature of Ar_3-10°C or more to a cooling stop temperature of 500°C to 650°C at a cooling rate of 5°C/s or more after hot rolling, and then immediately performing reheating to 550°C to 750°C at a heating rate of 0.5°C/s or more.

CITATION LIST

PATENT LITERATURE

[0005] Patent Literature 1: JP-A-2015-224376

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] However, the technique in Patent Literature 1 has a problem in that the yield ratio of the base metal of the clad steel sheet is increased by reheating after accelerated cooling. Furthermore, there is a problem in that cracking occurs during welding or weldability is deteriorated.

[0007] Accordingly, an object of the present invention is to provide a base metal for clad steel having excellent low-temperature toughness and a low yield ratio, and a clad steel including the base metal.

SOLUTION TO PROBLEM

[0008] That is, a base metal for clad steel according to an embodiment of the present invention includes a composition containing: in terms of mass%, C of 0.04% to 0.10%; Si of 0.10% to 0.30%; Mn of 1.30% to 1.60%; P of 0.015% or less; S of 0.005% or less; Ni of 0.10% to 0.50%; Cr of 0.10% or less; Cu of 0.05% or less; Mo of 0.05% to 0.40%; V of 0.02% to 0.06%; Nb of 0.03% or less; Ti of 0.005% to 0.025%; Al of 0.020% to 0.050%; N of 0.0030% to 0.0100%; and the balance being Fe and unavoidable impurities. In the composition, a carbon equivalent Ceq according to the following formula (1) is 0.400 or less, and a yield ratio Y.R. according to the following formula (2) is less than 0.80.

$$\text{Ceq} = \text{C} + \text{Mn}/6 + (\text{Ni} + \text{Cu})/15 + (\text{Cr} + \text{Mo} + \text{V})/5 \ (\text{mass\%}) \qquad \text{Formula (1)}$$

$$\text{Y.R.} = \text{Y.S. (MPa; 0.5\% Under load)/T.S. (MPa)} \qquad \text{Formula (2)}$$

[0009] According to the base metal for clad steel of another embodiment of the present invention, in the invention of the above aspect, Ti/N, which is a mass ratio of Ti content to N content, is in a range of 1.5 to 4.0.

[0010] According to the base metal for clad steel of another embodiment of the present invention, in the invention of the above aspect, the carbon equivalent according to the above formula (1) is $0.330 \leq Ceq \leq 0.400$, and weld cracking sensitivity Pcm according to the following formula (3) is within a range of 0.200 or less.

$$Pcm = C + Si/30 + Mn/20 + Ni/60 + Cr/20 + Cu/20 + Mo/15 + V/10 \text{ (mass\%)}$$

Formula (3).

[0011] In a clad steel according to one embodiment of the present invention, a cladding material is cladded on the base metal for clad steel according to any one of the above embodiments.

[0012] A method for producing a clad steel according to one embodiment of the present invention includes: melting an alloy steel for a base metal for clad steel to form a steel ingot; subjecting the steel ingot to clad rolling with a cladding material; quenching the clad steel from an austenitizing temperature range of 900°C to 980°C; and not tempering the clad steel, in which the base metal for clad steel includes a composition containing: in terms of mass%, C of 0.04% to 0.10%; Si of 0.10% to 0.30%; Mn of 1.30% to 1.60%; P of 0.015% or less; S of 0.005% or less; Ni of 0.10% to 0.50%; Cr of 0.10% or less; Cu of 0.05% or less; Mo of 0.05% to 0.40%; V of 0.02% to 0.06%; Nb of 0.03% or less; Ti of 0.005% to 0.025%; Al of 0.020% to 0.050%; N of 0.0030% to 0.0100%; and the balance being Fe and unavoidable impurities.

ADVANTAGEOUS EFFECTS OF INVENTION

[0013] According to the present invention, a base metal for clad steel having excellent low-temperature toughness and a low yield ratio can be obtained. The base metal for clad steel can be produced, for example, only by quenching after hot rolling, and a low yield ratio can be achieved. In addition, large-scale equipment such as controlled rolling is not required, and economic efficiency can be improved.

BRIEF DESCRIPTION OF DRAWINGS

[0014] [FIG. 1] FIG. 1 is a schematic view showing a clad steel 10 according to an embodiment of the present invention, a base metal 11 for clad steel according to the embodiment of the present invention and a cladding material 12 which constitute the clad steel 10.

DESCRIPTION OF EMBODIMENTS

[0015] Hereinafter, an embodiment of the present invention will be described in detail. The present invention is not limited to the embodiment described below.

<Base Metal for Clad Steel>

[0016] As shown in FIG. 1, a base metal 11 for clad steel according to an embodiment of the present invention constitutes a clad steel 10 together with a cladding material 12. Hereinafter, the base metal for clad steel will be described.

[0017] A base metal for clad steel according to one embodiment of the present invention includes a composition containing: in terms of mass%, C: 0.04% to 0.10%; Si: 0.10% to 0.30%; Mn: 1.30% to 1.60%; P: 0.015% or less; S: 0.005% or less; Ni: 0.10% to 0.50%; Cr: 0.10% or less; Cu: 0.05% or less; Mo: 0.05% to 0.40%; V: 0.02% to 0.06%; Nb: 0.03% or less; Ti: 0.005% to 0.025%; Al: 0.020% to 0.050%; N: 0.0030% to 0.0100%; and the balance being Fe and unavoidable impurities. In the composition, a carbon equivalent Ceq according to the following formula (1) is 0.400 or less, and a yield ratio (Y.R.) according to the following formula (2) is less than 0.80.

$$Ceq = C + Mn/6 + (Ni + Cu)/15 + (Cr + Mo + V)/5 \text{ (mass\%)} \qquad \text{Formula (1)}$$

$$Y.R. = Y.S. \text{ (MPa; 0.5\% Under load)}/T.S. \text{ (MPa)} \qquad \text{Formula (2)}$$

[0018] Hereinafter, limiting conditions of the composition and the like of the base metal for clad steel according to one embodiment of the present invention will be described. "%" in the composition range means "mass%".

C: 0.04% to 0.10%

[0019] C is an additive element necessary for securing strength. Therefore, a lower limit of the content of C in the base metal for clad steel is 0.04%. The lower limit is preferably 0.045%, and more preferably 0.05%.

[0020] On the other hand, the addition of more than 0.10% of C causes a decrease in toughness and a decrease in weldability due to an increase in strength. Therefore, an upper limit of the content of C in the base metal for clad steel is 0.10%. For the same reason, the upper limit is preferably 0.08%, and more preferably 0.07%.

Si: 0.10% to 0.30%

[0021] Si has a deoxidizing action at the time of melting steel, and needs to be contained in a predetermined amount or more in order to obtain sound steel. Si is an element necessary for ensuring strength. Therefore, a lower limit of the content of Si in the base metal for clad steel is 0.10%. The lower limit is preferably 0.11%, and more preferably 0.12%.

[0022] On the other hand, when Si is excessively contained, the toughness and the weldability are deteriorated, and thus an upper limit of the content of Si in the base metal for clad steel is 0.30%. For the same reason, the upper limit is preferably 0.20%, and more preferably 0.18%.

Mn: 1.30% to 1.60%

[0023] Mn is useful as a deoxidizing element similarly to Si, and contributes to improvement in hardenability of steel. In order to obtain this effect, a lower limit of the content of Mn in the base metal for clad steel is 1.30%. The lower limit is preferably 1.35%, and more preferably 1.40%.

[0024] On the other hand, excessive Mn content causes a decrease in the toughness. Therefore, an upper limit of the content of Mn in the base metal for clad steel is 1.60%. For the same reason, the upper limit is preferably 1.57%, and more preferably 1.55%.

P: 0.015% or Less

[0025] P is preferably contained as an impurity in a smaller amount in the base metal for clad steel, but an upper limit thereof is 0.015% which can be industrially realized. The upper limit is preferably 0.013%, and more preferably 0.012%.

S: 0.005% or Less

[0026] S is preferably contained as an impurity in a smaller amount in the base metal for clad steel, but an upper limit thereof is 0.005% which can be industrially realized. The upper limit is preferably 0.003% or less, and more preferably 0.002%.

Ni: 0.10% to 0.50%

[0027] Ni is an element necessary for securing strength by improving hardenability, and low-temperature toughness. Therefore, a lower limit of the content of Ni in the base metal for clad steel is 0.10%. For the same reason, the lower limit is preferably 0.15%, and more preferably 0.20%.

[0028] On the other hand, excessive Ni content impairs economic efficiency. Therefore, an upper limit of the Ni content in the base metal for clad steel is 0.50%. For the same reason, the upper limit is preferably 0.35%, and more preferably 0.33%.

Cr: 0.10% or Less

[0029] Cr improves the strength and toughness of the base metal, but as the content is increased, the strength is increased and the weld cracking sensitivity is increased. Therefore, an upper limit of the Cr content in the base metal for clad steel is 0.10%. For the same reason, the upper limit is preferably 0.05%, and more preferably 0.03%. A lower limit is not particularly limited, but is, for example, 0.01%.

Cu: 0.05% or Less

[0030] Cu is effective for improving the strength of the base metal, but excessive Cu content increases the weld cracking sensitivity. Therefore, an upper limit of the content of Cu in the base metal for clad steel is 0.05%. For the same reason, the upper limit is preferably 0.03%, and more preferably 0.02%. A lower limit is not particularly limited, but is, for example, 0.005%.

Mo: 0.05% to 0.40%

[0031] Mo is an element that improves the hardenability and improves the strength of the base metal after quenching, but when Mo is less than 0.05%, the effect cannot be sufficiently obtained. Therefore, a lower limit of the content of Mo in the base metal for clad steel is 0.05%. For the same reason, the lower limit is preferably 0.08%, and more preferably 0.10%.

[0032] Since the excessive content of Mo causes a decrease in the toughness, an upper limit of the content of Mo in the base metal for clad steel is 0.40%. For the same reason, the upper limit is preferably 0.20%, and more preferably 0.18%.

V: 0.02% to 0.06%

[0033] V is an important element for ensuring the strength of steel. V has an effect of securing T.S. to be described later, contributes to refinement of crystal grains, and has an effect of securing impact characteristics without tempering. In order to sufficiently obtain these effects, a lower limit of the content of V in the base metal for clad steel is 0.02%. For the same reason, the lower limit is preferably 0.023%, and more preferably 0.025%.

[0034] On the other hand, since excessive addition of V adversely affects the toughness, an upper limit of the content of V in the base metal for clad steel is 0.06%. For the same reason, the upper limit is preferably 0.05%, and more preferably 0.04%.

Nb: 0.03% or Less

[0035] Nb is effective in preventing coarsening of austenite grains and in improving refinement of crystal grains and strength by uniformly dispersing fine Nb carbides and the like in a base metal when steel is heated to a quenching temperature. However, excessive content causes deterioration of the toughness due to coarsening of Nb carbide. Therefore, an upper limit of the Nb content in the base metal for clad steel is 0.03%. For the same reason, the upper limit is preferably 0.028%, and more preferably 0.027%. A lower limit is not particularly limited, but is, for example, 0.005%.

Ti: 0.005% to 0.025%

[0036] Ti has an effect of forming carbides and nitrides finely dispersed in steel and refining austenite grains. As will be described later, nitride formed by bonding with N has an effect of preventing coarsening of crystal grains in a heat-affected zone at the time of welding. Therefore, when the content of Ti is less than 0.005%, the above effect is small. When the content of Ti exceeds 0.025%, the toughness is greatly deteriorated due to a notch effect due to aggregation and coarsening of carbides and nitrides.

[0037] For the above reason, a lower limit of the Ti content in the base metal for clad steel is 0.005%. The lower limit is preferably 0.010%, and more preferably 0.012%. An upper limit of the Ti content in the base metal for clad steel is 0.025%. The upper limit is preferably 0.020%, and more preferably 0.018%.

Al: 0.020% to 0.050%

[0038] Al is an element effective as a deoxidizing agent. Precipitated AlN prevents coarsening of austenite grains during quenching, but when Al is less than 0.020%, the effect cannot be sufficiently obtained. Therefore, a lower limit of the content of Al in the base metal for clad steel is 0.020%. For the same reason, the lower limit is preferably 0.023%, and more preferably 0.025%.

[0039] On the other hand, when Al is contained in an amount of more than 0.050%, the grain refinement effect is reduced, and a toughness value is saturated. Therefore, an upper limit of the Al content in the base metal for clad steel is 0.050%. For the same reason, the upper limit is preferably 0.040%, and more preferably 0.035%.

N: 0.0030% to 0.0100%

[0040] N reacts with Ti and precipitates as TiN in steel, which is effective for refinement of crystal grains. Since TiN has high solute temperature and stably exists even at a relatively high temperature, it is very effective to prevent coarsening of crystal grains in the heat-affected zone and improve the toughness of the heat-affected zone. On the other hand, when the addition amount is too small, a sufficient effect cannot be obtained. Therefore, a lower limit of the content of N in the base metal for clad steel is 0.0030%. For the same reason, the lower limit is preferably 0.0035%, and more preferably 0.0040%.

[0041] On the other hand, when N exceeds 0.0100%, the solute N is increased, and the toughness of the heat-affected zone is decreased. Therefore, an upper limit of the content of N in the base metal for clad steel is 0.0100%. For the same reason, the upper limit is preferably 0.0080%, and more preferably 0.0070%.

[0042] In the base metal for clad steel according to the present embodiment, the balance other than the above elements is Fe and unavoidable impurities. Examples of the unavoidable impurities include O and H.

Ti/N: 1.5 to 4.0

[0043] By appropriately adjusting a mass ratio of Ti and N, TiN which is stably and finely dispersed can be generated, and coarsening of crystal grains in the heat-affected zone of the base metal can be prevented at the time of welding. Therefore, the mass ratio of Ti/N is adjusted as desired. When a lower limit of the mass ratio of Ti/N is 1.5, a sufficient effect of preventing coarsening of crystal grains can be obtained. For the same reason, the lower limit is more preferably 1.7, and still more preferably 2.0.

[0044] On the other hand, when an upper limit of the mass ratio of Ti/N is 4.0, it is possible to prevent a decrease in the toughness of the base metal due to excessive precipitation of TiN and coarsening of TiN. For the same reason, the upper limit is more preferably 3.9, and still more preferably 3.85.

[0045] The base metal for clad steel according to the present embodiment has a carbon equivalent Ceq: 0.400 or less. The reason why the carbon equivalent is limited will be described below.

[0046] Alloy elements are added in order to improve the hardenability of steel and provide desired strength, toughness, and other properties. In order to produce a steel sheet having high strength and high toughness, it is necessary to increase the amount of alloy elements to be added. However, while an increase in the amount of alloy elements to be added is effective for increasing the strength, in the heat treatment, when the carbon equivalent is too high, the strength becomes too high and the yield ratio is increased. Therefore, an upper limit of the carbon equivalent (Ceq) represented by the following formula (1) is 0.400.

$$Ceq = C + Mn/6 + (Ni + Cu)/15 + (Cr + Mo + V)/5 \text{ (mass\%)} \qquad \text{Formula (1)}$$

[0047] Since a suitable strength is required for the base metal for clad steel, a lower limit of the carbon equivalent is preferably 0.330. That is, it is preferable to satisfy $0.330 \leq Ceq \leq 0.400$. The lower limit of the carbon equivalent (Ceq) is more preferably 0.335, and still more preferably 0.340. An upper limit of the carbon equivalent (Ceq) is preferably 0.390, and more preferably 0.385.

[0048] In the base metal for clad steel according to the present embodiment, the yield ratio Y.R. is less than 0.80 (yield ratio Y.R. < 0.80). The reason why the yield ratio Y.R. is limited will be described below.

[0049] The yield ratio is represented by a ratio of T.S. (tensile strength) to Y.S. (MPa; 0.5% Under load) (yield strength), as shown in the following formula (2). Here, T.S. (tensile strength) means a value obtained by dividing the maximum load by an original cross-sectional area of a parallel portion of a test piece. Y.S. means 0.5% under load (0.5% under load proof stress), that is, a stress when a total elongation is 0.5% with respect to an elongation gauge length. Preventing the yield ratio Y.R. low means widening tolerance from the start of plastic deformation (Y.S (MPa; 0.5% under load)) to non-uniform deformation (occurrence of constriction), and contributes to improvement in safety of the structure. Therefore, in the base metal for clad steel according to the present embodiment, the yield ratio Y.R. is less than 0.80.

$$\text{Y.R.} = \text{Y.S. (MPa; 0.5\% Under load)/T.S. (MPa)} \qquad \text{Formula (2)}$$

[0050] A lower limit of the yield ratio Y.R is usually 0.60.

[0051] The T.S (tensile strength) and Y.S (yield strength) can be measured by performing a tensile test at room temperature in accordance with JIS Z2241: 2011 using a No. 10 round bar test piece. Specifically, a test is performed on a test piece having a parallel portion diameter of 12.5 mm and a gauge length of the test piece of 50 mm, and the T.S and Y.S can be obtained from a stress-strain curve.

[0052] In the base metal for clad steel according to the present embodiment, the weld cracking sensitivity Pcm is preferably within a range of 0.200 or less ($Pcm \leq 0.200$). The reason why the weld cracking sensitivity Pcm is limited will be described below.

[0053] Alloy elements are added in order to improve the hardenability of steel and provide desired strength, toughness, and other properties. In order to produce a steel sheet having high strength and high toughness, it is necessary to increase the amount of the alloy elements to be added. An increase in the amount of the alloy element to be added is effective in increasing the strength, but causes hardening of the heat-affected zone during welding, resulting in occurrence of weld cracking and deterioration of weldability. Therefore, it is preferable to define a component range by the weld cracking sensitivity (Pcm) represented by the following formula (3).

$$Pcm = C + Si/30 + Mn/20 + Ni/60 + Cr/20 + Cu/20 + Mo/15 + V/10 \text{ (mass\%)}$$

Formula (3)

[0054] The weld cracking sensitivity Pcm is more preferably 0.195 or less, and still more preferably 0.190 or less. A lower limit is not particularly limited, and is, for example, 0.100.

[0055] The base metal for clad steel according to the present embodiment is obtained by quenching as described later. The reason why a quenching temperature is limited will be described below.

Quenching temperature: 900°C to 980°C

[0056] The quenching temperature is a temperature at which a precipitate of a cladding material described later is sufficiently dissolved in solid, and corresponds to a quenchable temperature of the base metal. In order to obtain these effects, the lower limit thereof is preferably 900°C. The lower limit is more preferably 910°C, and still more preferably 920°C.

[0057] On the other hand, an upper limit of the quenching temperature is preferably 980°C in order to prevent the crystal grains of the base metal from becoming coarse and the impact characteristics from deteriorating. The upper limit is more preferably 977°C, and still more preferably 975°C.

[0058] In the base metal for clad steel according to the present embodiment, a heat treatment at the time of producing is only quenching, and tempering is not performed, so that the formation of precipitates by tempering is reduced, and an increase in Y.S. (yield strength) is prevented, thereby realizing a low yield ratio. By not performing tempering, decomposition of a hard phase generated at the time of quenching can be prevented, a decrease in T.S (tensile strength) due to decomposition of the hard phase can also be prevented, and a low yield ratio can be realized.

[0059] <Clad Steel>

[0060] As shown in FIG. 1, the clad steel 10 according to the embodiment of the present invention is obtained by cladding the following cladding material 12 on the base metal 11 for clad steel described above.

Cladding Material

[0061] In the clad steel according to the present embodiment, the cladding material is not limited to a specific material. As the cladding material, for example, a steel standardized by ISO, JIS, or ASTM is applied. Specifically, as typical examples, austenitic stainless steels SUS304L, 316L, and 317L, Ni-based alloys Alloy 625 and Alloy 825, and the like can be used.

[0062] A cladding ratio (= plate thickness of base metal for clad steel/plate thickness of entire clad steel) is not particularly limited, but may be, for example, 0.60 to 0.90.

<Base Metal for Clad Steel and Method for Producing Clad Steel>

[0063] Hereinafter, a base metal for clad steel according to the embodiment of the present invention and a method for producing clad steel in which a cladding material is clad on the base metal will be described.

[0064] First, an alloy steel for a base metal for clad steel that includes the following composition is melted to obtain a steel ingot, and then a hot-rolled slab is produced. That is, an alloy steel for a base metal for clad steel is melted by a traditional method to obtain a steel ingot, and a hot-rolled slab is produced, in which the base metal for clad steel contains, in terms of mass%, C: 0.04% to 0.10%, Si: 0.10% to 0.30%, Mn: 1.30% to 1.60%, P: 0.015% or less, S: 0.005% or less, Ni: 0.10% to 0.50%, Cr: 0.10% or less, Cu: 0.05% or less, Mo: 0.05% to 0.40%, V: 0.02% to 0.06%, Nb: 0.03% or less, Ti: 0.005% to 0.025%, Al: 0.020% to 0.050%, N: 0.0030% to 0.0100%, and the balance being Fe and unavoidable impurities. The method of producing a steel ingot and a hot-rolled slab is not particularly limited, and the steel ingot and the hot-rolled slab can be produced by any known traditional method.

[0065] Subsequently, the obtained hot-rolled slab and the cladding material are cladding-rolled. The method of clad rolling is not particularly limited, and any known traditional method can be used. The materials described above can be used as the cladding material. When a total thickness of two overlapped hot-rolled slabs is 100 mm or less, clad rolling and quenching described later can be performed in two overlapped hot-rolled slabs. In the present embodiment, the conditions for the clad rolling are not particularly limited.

[0066] After the clad rolling, the hot-rolled plate is heated to a temperature range of 900°C to 980°C and quenched from an austenite temperature range. Here, the austenite temperature range means a range exceeding a temperature at which a microstructure of steel is an austenite single phase, that is, a temperature at which ferrite transformation starts at the time of cooling. A rising temperature at the time of quenching is not particularly limited. The cooling is preferably performed by water quenching. When a method having a cooling rate lower than that of water quenching, such as oil quenching or FAN cooling, is selected as the cooling method, ferrite may be generated during cooling, and desired strength characteristics may not be obtained.

[0067] As described above, the base metal for clad steel and the clad steel including the base metal for clad steel are obtained. The obtained base metal for clad steel has the yield ratio of Y.R. < 0.80.

Example

[0068] Hereinafter, the present invention will be described in more detail with reference to Examples, but the present invention is not limited to these Examples.

1. Production of Base Metal for Clad Steel

[0069] A base metal for clad steel according to an embodiment of the present invention was produced as follows. In the present example, a cladding material is not used, but the presence or absence of the cladding material does not affect the material property evaluation described later, and thus there is no problem in the evaluation of the base metal for clad steel.

[0070] First, slabs (steel type A and steel type B) including a composition (mass%, the balance is Fe and other unavoidable impurities) shown in Table 1 were produced by continuous casting, and hot rolling was performed to produce a steel sheet having a thickness of 24 mm on the assumption that the steel sheet was used as a base metal for clad steel. Thereafter, each of the steel sheets obtained from the steel types A and B was quenched at 975°C for 30 minutes to obtain base metals for clad steel in Examples 1 and 2. As a comparative example, after quenching the steel sheet obtained from the steel type A, tempering was performed at three temperatures of 400°C, 500°C, and 580°C for 2 hours to obtain base metals for clad steel in Comparative Examples 1 to 3.

[Table 1]

Steel type	C	Si	Mn	P	S	Ni	Cr	Cu	Mo	V	Nb	Ti	Al	N	Ceq	Pcm	Ti/N
A	0.05	0.13	1.45	0.010	0.0007	0.22	0.02	0.02	0.13	0.03	0.024	0.013	0.028	0.0049	0.34	0.14	2.65
B	0.06	0.13	1.54	0.012	0.0007	0.27	0.02	0.03	0.15	0.03	0.030	0.018	0.034	0.0047	0.38	0.16	3.83

2. Tensile Strength and Impact Characteristics of Base Metal

[0071] A tensile test and a Charpy impact test were performed as the evaluation of the material properties of the obtained base metals for clad steel in Examples and Comparative Examples. Both tests were performed twice for each test material. Test pieces were sampled such that a longitudinal direction of the test pieces was perpendicular to a rolling direction in both the tensile test and the Charpy impact test.

[0072] The tensile test was performed at room temperature using a No. 10 round bar test piece in accordance with JIS Z2241: 2011.

[0073] The Charpy impact test was evaluated according to JIS Z2242: 2018 using a test machine having a pendulum hammer with a radius of 2 mm by using a V-notch test piece. Specifically, two tests were performed at -60°C in order to determine the impact characteristics (J) at -60°C by using a V-notch Charpy impact test piece having a square cross section with a length of 55 mm and a side of 10 mm and provided with a V-groove having a notch angle of 45°, a notch depth of 2 mm, and a notch bottom radius of 0.25 mm at a center of the length of the test piece.

[0074] The evaluation results were shown in Table 2 below.

[Table 2]

Test material	Steel type	Heat treatment conditions	Base metal tensile strength			Impact characteristics vE-60 (J)
			YS. (0.5% Under Load) (MPa)	T.S. (MPa)	Y.R.	
Example 1	A	Only quenching at 975°C	454 446	575 572	0.79 0.78	375 342
Example 2	B	Only quenching at 975°C	447 446	590 589	0.76 0.76	485 481
Comparative Example 1	A	Quenching at 975°C + tempering at 400°C	450 449	546 545	0.82 0.82	378 396
Comparative Example 2		Quenching at 975°C + tempering at 500°C	454 449	536 536	0.85 0.84	385 382
Comparative Example 3		Quenching at 975°C + tempering at 580°C	454 449	546 544	0.86 0,85	397 395

[0075] As shown in Table 2, in the cases of Example 1 and Example 2 in which only quenching was performed, the low-temperature toughness was substantially equal to that in the case of performing quenching and tempering treatment, which was good, whereas the yield ratio (Y.R.) could be maintained in a low state of less than 0.80.

[0076] On the other hand, in Comparative Examples 1 to 3 in which tempering was also performed after quenching, the yield ratio (Y.R.) exceeded 0.80, and the yield ratio could not be maintained in a low state.

[0077] Although the embodiments are described above with reference to the drawings, it is needless to say that the present invention is not limited to such examples. It will be apparent to those skilled in the technique that various changes and modifications may be conceived within the scope of the claims. It is also understood that the various changes and modifications belong to the technical scope of the present invention. Constituent elements in the embodiments described above may be combined freely within a range not departing from the purpose of the present invention.

[0078] The present application is based on Japanese Patent Application (Japanese Patent Application No. 2019-049681) filed on March 18, 2019, and the contents thereof are incorporated herein by reference.

INDUSTRIAL APPLICABILITY

[0079] The present invention relates to a clad steel sheet suitably usable for a pipeline for natural gas transportation.

REFERENCE SIGNS LIST

[0080]

10 Clad steel
11 Base metal for clad steel
12 Cladding material

Claims

1. A base metal for clad steel that includes a composition containing:

in terms of mass%,
C: 0.04% to 0.10%;
Si: 0.10% to 0.30%;
Mn: 1.30% to 1.60%;
P: 0.015% or less;
S: 0.005% or less;
Ni: 0.10% to 0.50%;
Cr: 0.10% or less;
Cu: 0.05% or less;
Mo: 0.05% to 0.40%;
V: 0.02% to 0.06%;
Nb: 0.03% or less;
Ti: 0.005% to 0.025%;
Al: 0.020% to 0.050%;
N: 0.0030% to 0.0100%; and
the balance being Fe and unavoidable impurities,
wherein in the composition, a carbon equivalent Ceq according to the following formula (1) is 0.400 or less, and wherein a yield ratio Y.R. according to the following formula (2) is less than 0.80:

$$Ceq = C + Mn/6 + (Ni + Cu)/15 + (Cr + Mo + V)/5 \text{ (mass\%)} \qquad \text{Formula (1)}$$

$$Y.R. = Y.S. \text{ (MPa; 0.5\% Under load)}/T.S. \text{ (MPa)} \qquad \text{Formula (2).}$$

2. The base metal for clad steel according to claim 1,
wherein in the composition, Ti/N, which is a mass ratio of Ti content and N content, is in a range of 1.5 to 4.0.

3. The base metal for clad steel according to claim 1 or 2,

wherein in the composition, the carbon equivalent according to the formula (1) is 0.330 ≤ Ceq ≤ 0.400, and wherein weld cracking sensitivity Pcm according to the following formula (3) is within a range of 0.200 or less:

$$Pcm = C + Si/30 + Mn/20 + Ni/60 + Cr/20 + Cu/20 + Mo/15 + V/10 \text{ (mass\%)} \qquad \text{Formula (3).}$$

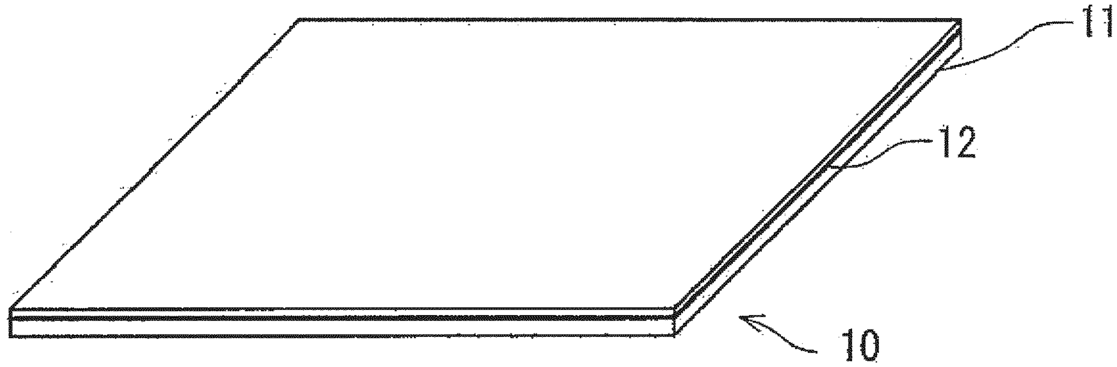
4. A clad steel,
wherein a cladding material is clad on the base metal for clad steel according to any one of claims 1 to 3.

5. A method for producing a clad steel, comprising:

melting an alloy steel for a base metal for clad steel to form a steel ingot;
subjecting the steel ingot to clad rolling with a cladding material;
then quenching the clad steel from an austenitizing temperature range of 900°C to 980°C; and
not tempering the clad steel,
wherein the base metal for clad steel includes a composition containing: in terms of mass%, C: 0.04% to 0.10%; Si: 0.10% to 0.30%; Mn: 1.30% to 1.60%; P: 0.015% or less; S: 0.005% or less; Ni: 0.10% to 0.50%; Cr: 0.10%

or less; Cu: 0.05% or less; Mo: 0.05% to 0.40%; V: 0.02% to 0.06%; Nb: 0.03% or less; Ti: 0.005% to 0.025%; Al: 0.020% to 0.050%; N: 0.0030% to 0.0100%; and the balance being Fe and unavoidable impurities.

Figure



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/011681

A. CLASSIFICATION OF SUBJECT MATTER
C21D 9/00(2006.01)i; C22C 38/00(2006.01)i; C22C 38/58(2006.01)i
FI: C22C38/00 301A; C22C38/58; C21D9/00 Z

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)
C21D9/00; C22C38/00-C22C38/60; C21D8/02; C21D9/46; B21B1/22; B21B1/38; B21C37/00-B21C37/06; B32B15/00

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2020
Registered utility model specifications of Japan	1996-2020
Published registered utility model applications of Japan	1994-2020

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	JP 2004-149821 A (THE JAPAN STEEL WORKS, LTD.) 27.05.2004 (2004-05-27) entire text, all drawings	1-5
A	JP 2009-185368 A (THE JAPAN STEEL WORKS, LTD.) 20.08.2009 (2009-08-20) entire text	1-5
A	JP 2016-108665 A (JFE STEEL CORPORATION) 20.06.2016 (2016-06-20) entire text	1-5
A	JP 2019-7056 A (JFE STEEL CORPORATION) 17.01.2019 (2019-01-17) entire text	1-5
A	US 2016/0052080 A1 (HUNTINGTON ALLOYS CORPORATION) 25.02.2016 (2016-02-25) entire text, all drawings	1-5

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 June 2020 (04.06.2020)	16 June 2020 (16.06.2020)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/011681

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2013-0053706 A (SAMSUNG HEAVY IND. CO., LTD.) 24.05.2013 (2013-05-24) entire text, all drawings	1-5

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/011681

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2004-149821 A	27 May 2004	EP 1416059 A1 entire text, all drawings	
JP 2009-185368 A	20 Aug. 2009	EP 2128294 A1 entire text	
JP 2016-108665 A	20 Jun. 2016	(Family: none)	
JP 2019-7056 A	17 Jan. 2019	(Family: none)	
US 2016/0052080 A1	25 Feb. 2016	WO 2016/028992 A1 entire text, all drawings EP 3183074 A1 CN 106852131 A	
KR 10-2013-0053706 A	24 May 2013	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2015224376 A **[0005]**
- JP 2019049681 A **[0078]**