

LOW HYDROGEN-BASED COVERED ELECTRODE

Technical Field

[0001]

The present invention relates to a low hydrogen-based covered electrode.

Background Art

[0002]

Low hydrogen-based covered electrodes for high tensile steel (hereinafter appropriately referred to as covered electrodes or simply electrodes) have hitherto been variously developed. As one example thereof, Patent Document 1 discloses a low hydrogen-based covered electrode to be used for high tensile steel having a 950 MPa class tensile strength. In this covered electrode, it is made possible to improve low-temperature toughness due to a decrease in the amount of oxygen in weld metal and to improve cracking resistance due to a decrease in the amount of hydrogen, by specifying the contents of a metal carbonate, a metal fluoride, Mg and the like, the baking temperature and the like. Further, in the covered electrode described in Patent Document 1, the proper amounts of the metal carbonate and the metal fluoride which can secure a diffusible hydrogen amount of 5 ml/100 g or less in the weld metal are specified.

[0003]

Furthermore, Patent Document 2 discloses a low hydrogen-based covered electrode to be used for high tensile steel having a tensile strength of 880 MPa or more. In this covered electrode, the optimum component ranges of a metal carbonate, a metal fluoride and the like are specified, and further, an appropriate amount of B is added for the purpose of suppressing crack occurrence and crack propagation at grain boundaries due to a decrease in grain boundary energy. Thanks to these features, good cracking resistance is secured.

[0004]

In addition, in a low hydrogen-based covered electrode of Patent Document 3, the proper amounts of a metal carbonate, a metal oxide and a metal fluoride are

specified, and good welding performance in all-position welding is realized while securing a diffusible hydrogen amount of 3 ml/100 g or less.

Citation List

Patent Documents

[0005]

[Patent Document 1] JP-A-H09-327793

[Patent Document 2] JP-A-H11-123589

[Patent Document 3] JP-A-2010-110817

Summary of the Invention

Technical Problem

[0006]

In the covered electrode described in Patent Document 1, the diffusible hydrogen amount in the weld metal is 5 ml/100 g or less. However, with respect to cracking resistance in a welding operation taking into consideration an extremely thick plate, it is desirable to apply a severer standard to the diffusible hydrogen amount in the weld metal.

In the covered electrode described in Patent Document 2, the diffusible hydrogen amount in the weld metal is from 3 to 5 ml/100 g. However, with respect to cracking resistance of high tensile steel having a tensile strength level of 780 MPa or more (690 MPa or more class yield strength level), it is desirable to apply a severer standard to the diffusible hydrogen amount in the weld metal. Further, in Patent Document 2, toughness in a low-temperature region of about -60°C is not conscious in any way.

In the covered electrode described in Patent Document 3, cracking resistance of the weld metal is improved, but in order to further improve cracking resistance, it is desirable to improve moisture absorption resistance of a covering. Further, from the viewpoint of productivity, it is also desirable to take into consideration adhesion of the covering.

[0007]

Furthermore, in the covered electrode, it has been desired to achieve good welding performance, in addition to improvements in cracking resistance, strength and toughness of the weld metal and improvements in moisture absorption resistance and adhesion of the covering. The term “welding performance” in the present application means qualities of arc stability, slag detachability and bead shape.

[0008]

It is therefore an object of the present invention to provide a low hydrogen-based covered electrode having excellent cracking resistance, strength and toughness of a weld metal, having good welding performance in all-position welding and having excellent moisture absorption resistance and adhesion of a covering, in welding of a high tensile steel having a 690 MPa or more class yield strength.

Technical Solution

[0009]

In order to achieve the above object, the present invention provides the following technical solution.

The low hydrogen-based covered electrode in the present invention includes a steel core wire coated with a covering, and in the low hydrogen-based covered electrode,

the covering contains, based on a total mass of the low hydrogen-based covered electrode,

a metal carbonate: 3.0% to 7.5% by mass on a CO₂ basis,

a metal fluoride: 0.9% to 3.0% by mass on a F basis,

TiO₂ ≤ 0.30% by mass,

ZrO₂: 0.4% to 1.8% by mass,

Al₂O₃ ≤ 0.15% by mass,

a Li compound: 0.01% to 0.12% by mass on a Li basis, and

a total of a Na compound on a Na basis and a K compound on a K basis: 0.30% to 0.90% by mass, and

the low hydrogen-based covered electrode contains, based on the total mass of the low hydrogen-based covered electrode,

a total of Mo and Cr: 0.06% to 1.20% by mass,

C≤0.06% by mass,

a total of Si and SiO₂: 1.5% to 3.0% by mass on a Si basis,

Mn: 0.9% to 2.7% by mass, and

Ni: 1.2% to 3.0% by mass.

[0010]

According to the low hydrogen-based covered electrode having such a structure, in the covering, the contents of the metal carbonate on a CO₂ basis, the metal fluoride on a F basis, TiO₂, ZrO₂, Al₂O₃, the Li compound on a Li basis, and the total of the Na compound on a Na basis and the K compound on a K basis, based on the total mass of the low hydrogen-based covered electrode, are specified, thereby obtaining a weld metal having excellent cracking resistance, strength and toughness. Further, welding performance is improved, and moisture absorption resistance and adhesion of the covering are improved.

Furthermore, in the low hydrogen-based covered electrode, the contents of the total of Mo and Cr, C, the total of Si and SiO₂ on a Si basis, Mn and Ni, based on the total mass of the low hydrogen-based covered electrode, are specified, thereby obtaining the weld metal having excellent cracking resistance, strength and toughness. In addition, coating properties of the covering are improved, and the bead shape of the weld metal is improved. Moreover, the occurrence of blowholes is suppressed.

[0011]

Further, in the low hydrogen-based covered electrode in the present invention, the covering preferably contains 1.2% by mass or more of Fe based on the total mass of the low hydrogen-based covered electrode.

According to such a feature, the deposition rate is more improved.

[0012]

Furthermore, in the low hydrogen-based covered electrode in the present invention, the metal carbonate preferably contains a metal carbonate having a particle diameter of 75 μm or less in an amount of from 50% to 80% by mass based on a total mass of the metal carbonate.

According to such a feature, the diffusible hydrogen amount tends to be decreased, and arc stability is more improved.

[0013]

In addition, in the low hydrogen-based covered electrode in the present invention, a value of the following equation (1) is from 5 to 50.

$$(1.22 \times [\text{Na}] + 1.49 \times [\text{K}]) / [\text{Li}] \cdots (1)$$

wherein [Na] is a content (% by mass) of the Na compound on a Na basis in the covering, [K] is a content (% by mass) of the K compound on a K basis in the covering and [Li] is a content (% by mass) of the Li compound on a Li basis in the covering.

According to such a feature, coating properties and moisture absorption resistance of the covering are more improved.

Advantageous Effects of the Invention

[0014]

According to the low hydrogen-based covered electrode in the present invention, a weld metal having excellent cracking resistance, strength and toughness can be obtained in welding of a high tensile steel having a 690 MPa or more class yield strength. Further, welding performance in all-position welding is improved in welding of the high tensile steel having a 690 MPa or more class yield strength. Furthermore, the covering has excellent moisture absorption resistance and adhesion.

Description of Embodiment

[0015]

Embodiments of the present invention will be described in detail below.

The low hydrogen-based covered electrode in the present invention includes a steel core wire coated with a covering, and the covering contains, based on the total mass of the low hydrogen-based covered electrode, predetermined amounts of a metal carbonate, a metal fluoride, TiO_2 , ZrO_2 , Al_2O_3 and a Li compounds and a predetermined amount of a Na compound and a K compound as the total amount thereof.

Further, the low hydrogen-based covered electrode contains, based on the total mass of the low hydrogen-based covered electrode, predetermined amounts of C, Mn and Ni, a predetermined amount of Mo and Cr as the total amount thereof, and a predetermined amount of Si and SiO_2 as the total amount thereof.

The content of the metal carbonate is on a CO_2 basis, the content of the metal fluoride is on a F basis, the content of the Li compound is on a Li basis, and the content of the total of the Na compound and the K compound is the content of the total of the Na compound on a Na basis and the K compound on a K basis. Further, the content of the total of Si and SiO_2 is on a Si basis.

Reasons for limiting the components of the low hydrogen-based covered electrode will be described below.

[0016]

<Covering>

The covering covers around the steel core wire as a flux component.

In the covering, the contents of the metal carbonate on a CO_2 basis, the metal fluoride on a F basis, TiO_2 , ZrO_2 , Al_2O_3 , the Li compound on a Li basis, and the total of the Na compound on a Na basis and the K compound on a K basis, based on the total mass of the covered electrode, will be described below.

[0017]

[Metal Carbonate: 3.0% to 7.5% by mass on a CO_2 basis]

When the content of the metal carbonate is less than 3.0% by mass on a CO_2 basis, the gas generation amount is insufficient, resulting in a failure to keep good shielding properties. For this reason, the amounts of hydrogen and nitrogen in the weld metal are increased to cause deterioration of the toughness and cracking resistance of the weld metal. On the other hand, when the content of the metal carbonate exceeds 7.5% by mass on a CO_2 basis, arc would be unstable, and the amount of spatter is increased.

Thus, the content of the metal carbonate in the covering ranges from 3.0% to 7.5% by mass on a CO_2 basis, based on the total mass of the covered electrode. From the viewpoint of more improving the toughness and cracking resistance of the weld metal, the content of the metal carbonate on a CO_2 basis is preferably 3.5% by mass or more, and more preferably 4.0% by mass or more. Further, from the viewpoint of more improving arc stability, it is preferably 7.0% by mass or less, and more preferably 6.5% by mass or less.

[0018]

[Metal Fluoride: 0.9% to 3.0% by mass on a F basis]

When the content of the metal fluoride is less than 0.9% by mass on a F basis, the viscosity of molten slag is insufficient, resulting in deterioration of the bead shape. On the other hand, when the content of the metal fluoride exceeds 3.0% by mass on a F basis, arc would be unstable.

Thus, the content of the metal fluoride in the covering ranges from 0.9% to 3.0% by mass on a F basis, based on the total mass of the covered electrode. From the viewpoint of more improving the bead shape, the content of the metal fluoride is preferably 1.5% by mass or more on a F basis. Further, from the viewpoint of more improving arc stability, it is preferably 2.7% by mass or less.

[0019]

[TiO₂ ≤ 0.30% by mass]

TiO₂ increases the oxygen amount and the amount of Ti dissolved in solid in the weld metal. TiC precipitates on a reheating part in multilayer welding by containing TiO₂, so that acicular nucleation ability is decreased. Coarse lath-like bainite is formed thereby, resulting in a decrease in the toughness of the weld metal. Accordingly, the content of TiO₂ should be suppressed. However, TiO₂ is allowed to be contained in an amount up to 0.30% by mass based on the total amount of the covered electrode.

Thus, the content of TiO₂ in the covering is 0.30% by mass or less. From the viewpoint of more improving the toughness of the weld metal, the content of TiO₂ is preferably 0.20% by mass or less, and more preferably 0.10% by mass or less.

Although the content of TiO₂ is preferably 0% by mass, it is difficult to control the content of TiO₂ to be 0% by mass. Therefore, the lower limit thereof may be 0.002% by mass.

[0020]

[ZrO₂: 0.4% to 1.8% by mass]

The bead shape and bead appearance can be improved by adding an appropriate amount of ZrO₂. When the content of ZrO₂ is less than 0.4% by mass, the effect as a slag-making agent is insufficient, resulting in deterioration of the bead shape. On the other hand, when the content of ZrO₂ exceeds 1.8% by mass, slag becomes glassy to cause deterioration of slag detachability.

Thus, the content of ZrO_2 ranges from 0.4% to 1.8% by mass based on the total mass of the covered electrode. From the viewpoint of more improving the bead shape, the content of ZrO_2 is preferably 0.6% by mass or more. Further, from the viewpoint of more improving slag detachability, it is preferably 1.5% by mass or less.

[0021]

$[\text{Al}_2\text{O}_3 \leq 0.15\% \text{ by mass}]$

In the covering, Al_2O_3 is usually added as the slag-making agent. However, in the present invention, it has been found that it is effective for improvement of slag detachability to more increase the content of SiO_2 in the covered electrode than that in the conventional one and to control the content of Al_2O_3 to 0.15% by mass or less without intentional addition thereof.

Thus, the content of Al_2O_3 is 0.15% by mass or less based on the total mass of the covered electrode. From the viewpoint of more improving slag detachability, the content of Al_2O_3 is preferably 0.10% by mass or less, and more preferably 0.05% by mass or less.

Although the content of Al_2O_3 is preferably 0% by mass, it is difficult to control the content of Al_2O_3 to be 0% by mass. Therefore, the lower limit thereof may be 0.002% by mass.

[0022]

$[\text{Li Compound: } 0.01\% \text{ to } 0.12\% \text{ by mass on a Li basis}]$

Li is usually added in water glass for the purpose of improving moisture absorption resistance of the covering. When the content of the Li compound is less than 0.01% by mass on a Li basis, an effect of improving moisture absorption resistance of the covering is not obtained. On the other hand, when the content of the Li compound exceeds 0.12% by mass on a Li basis, the viscosity of the water glass is decreased to deteriorate performance as a lubricant in a covering step of the covering, although excellent moisture absorption resistance is obtained. A covering operation becomes difficult thereby, and adhesion strength is decreased, and thus, falling-off of the covering after covering and drying cracks during drying become liable to occur.

Thus, the content of the Li compound in the covering ranges from 0.01% to 0.12% by mass on a Li basis, based on the total mass of the covered electrode. From the viewpoint of more improving moisture absorption resistance of the covering, the

content of the Li compound on a Li basis is preferably 0.02% by mass or more, and more preferably 0.05% by mass or more. Further, from the viewpoints of more improving the covering operation and more suppressing the falling-off of the covering after covering and the occurrence of drying cracks during drying, it is preferably 0.10% by mass or less, and more preferably 0.08% by mass or less.

[0023]

[Total of Na compound on a Na basis and K compound on a K basis: 0.30% to 0.90% by mass]

Na and K are added for securing adhesion of the covering and arc stability. When the total content of the Na compound on a Na basis and the K compound on a K basis is less than 0.30% by mass, arc would be unstable, and the adhesion strength of the covering is decreased, and thus, the falling-off of the covering after covering and drying cracks during drying become liable to occur. On the other hand, when the total content of the Na compound on a Na basis and the K compound on a K basis exceeds 0.90% by mass, moisture absorption resistance of the covering is deteriorated.

Thus, the total content of the Na compound on a Na basis and the K compound on a K basis in the covering ranges from 0.30% to 0.90% by mass based on the total mass of the covered electrode. From the viewpoints of more improving arc stability and more suppressing the falling-off of the covering after covering and the occurrence of drying cracks during drying, the total content of the Na compound on a Na basis and the K compound on a K basis is preferably 0.40% by mass or more, and more preferably 0.50% by mass or more. Further, from the viewpoint of more improving moisture absorption resistance of the covering, it is preferably 0.80% by mass or less, and more preferably 0.70% by mass or less.

[0024]

[Remainder]

The covering is preferably composed of the above-mentioned respective components, and iron and unavoidable impurities. The remainder of the covering is mainly composed of various Fe alloys (such as Fe-Si, Fe-Mo and Fe-Cr) and Fe derived from iron powder. Further, as the unavoidable impurities include, examples thereof include P, S, V, Nb, Sn and the like. Furthermore, CaCO, BaCO and the like may also be included as the remainder.

[0025]

In the covering, the content of Fe based on the total mass of the covered electrode may be specified.

[Fe: 1.2% by mass or more]

As described above, the remainder of the covering is mainly composed of various Fe alloys (such as Fe-Si, Fe-Mo and Fe-Cr) and Fe derived from iron powder. When the Fe content is increased, the deposition rate is improved, which makes it possible to improve welding operation efficiency. In the present invention, when the Fe content is 1.2% by mass or more, the deposition rate is improved, resulting in improvement of welding operation efficiency.

Thus, the Fe content in the covering is preferably 1.2% by mass or more based on the total mass of the covered electrode. Although the upper limit thereof is not particularly specified, the Fe content may be, for example, 10.0% by mass or less.

[0026]

<Low Hydrogen-based Covered Electrode>

The contents of the total of Mo and Cr, C, the total of Si and SiO₂ on a Si basis, Mn and Ni, based on the total mass of the covered electrode, in the whole covered electrode, that is, in the whole electrode including the steel core wire and the covering, will be described below.

[0027]

[Total of Mo and Cr: 0.06% to 1.20% by mass]

The covered electrode can stably secure the strength of the weld metal by adding appropriate amounts of Cr and Mo. Cr and Mo may be added either by single addition of Cr or Mo, or by combined addition of Cr and Mo. However, when the total of the Mo content and the Cr content is less than 0.06% by mass, the strength of the weld metal cannot be sufficiently secured. On the other hand, when the total of the Mo content and the Cr content exceeds 1.20% by mass, the strength of the weld metal is excessively increased, and the toughness is deteriorated. Further, it also causes cold cracking.

Thus, the total of the Mo content and the Cr content in the whole covered electrode ranges from 0.06% to 1.20% by mass based on the total mass of the covered electrode. From the viewpoint of more suitably improving the strength of the weld

metal, the total of the Mo content and the Cr content is preferably 0.20% by mass or more, and more preferably 0.40% by mass or more. Further, from the viewpoints of more suppressing an excessive increase in the strength of the weld metal, more improving the toughness and suppressing cold cracking, it is preferably 1.0% by mass or less, and more preferably 0.80% by mass or less.

[0028]

[C: $\leq 0.06\%$ by mass]

C is an effective component in securing the strength of the weld metal. However, in the weld metal having a yield strength of 690 MPa or more, the strength becomes excessive by addition of C, and the toughness is deteriorated by the formation of island-shaped martensite.

Thus, the C content in the whole covered electrode is regulated to 0.06% by mass or less based on the total mass of the covered electrode. From the viewpoint of suppressing an excessive increase in the strength of the weld metal and deterioration of the toughness, the C content is preferably 0.04% by mass or less, and more preferably 0.02% by mass or less.

[0029]

[Total of Si and SiO₂ compound: 1.5% to 3.0% by mass on a Si basis]

Si is a deoxidizing agent, and is an element having effects of securing the strength of the weld metal and decreasing the oxygen amount. Further, it is necessary to add SiO₂ as a slag-making agent or a binder in the covering. When the total of the Si content and the SiO₂ content is less than 1.5% by mass on a Si basis, an effect as the slag-making agent or the deoxidizing agent cannot be obtained, and coating properties of the covering in the production are deteriorated, or the toughness of the weld metal is deteriorated by insufficient deoxidization. On the other hand, when the total of the Si content and the SiO₂ content exceeds 3.0% by mass on a Si basis, slag becomes glassy to cause deterioration of slag detachability, and the viscosity of the weld metal is increased to cause poor fitness to a base material, resulting in deterioration of the bead shape.

Thus, the total of the Si content and the SiO₂ content in the whole covered electrode ranges from 1.5% to 3.0% by mass on a Si basis, based on the total mass of the covered electrode. From the viewpoint of more improving coating properties of

the covering or more improving the toughness of the weld metal, the total of the Si content and the SiO₂ content on a Si basis is preferably 1.8% by mass or more, and more preferably 2.0% by mass or more. Further, from the viewpoints of more improving slag detachability and more improving the bead shape, it is preferably 2.7% by mass or less, and more preferably 2.6% by mass or less.

Although Si and SiO₂ are each an essential component, these individual contents are not particularly specified. As described above, it is only necessary that the total content of Si and SiO₂ on a Si basis should satisfy the specified value. However, from the viewpoints of improving the strength of the weld metal and improving the toughness, the content of Si preferably ranges from 0.3% to 1.5% by mass. Further, from the viewpoints of improving coating properties and improving the bead shape as the slag-making agent or the binder, the content of SiO₂ preferably ranges from 0.7% to 1.5% by mass on a Si basis.

[0030]

[Mn: 0.9% to 2.7% by mass]

Mn is an element effective for improvement of the toughness of the weld metal, and is added as the deoxidizing agent, similarly to Si. When the Mn content is less than 0.9% by mass, deoxidization becomes insufficient to cause the occurrence of blowholes. On the other hand, when the Mn content exceeds 2.7% by mass, the strength of the weld metal is excessively increased to increase cold cracking susceptibility.

Thus, the Mn content in the whole covered electrode ranges from 0.9% to 2.7% by mass based on the total mass of the covered electrode. From the viewpoint of more suppressing the occurrence of blowholes, the Mn content is preferably 1.0% by mass or more. Further, from the viewpoint of further decreasing cold cracking susceptibility, it is preferably 2.5% by mass or less.

[0031]

[Ni: 1.2% to 3.0% by mass]

Ni is an extremely important element for securing the strength and toughness of the weld metal. However, when the Ni content is less than 1.2% by mass, a sufficient toughness improving effect is not obtained. On the other hand, when the Ni

content exceeds 3.0% by mass, the possibility of the occurrence of hot cracking is increased.

Thus, the Ni content in the whole covered electrode ranges from 1.2% to 3.0% by mass based on the total mass of the covered electrode. From the viewpoint of more improving the toughness, the Ni content is preferably 1.5% by mass or more. Further, from the viewpoint of more decreasing the possibility of the occurrence of hot cracking, it is preferably 2.5% by mass or less.

[0032]

[Remainder]

The covered electrode is preferably composed of the above-mentioned respective components, and components excluded in the steel core wire and the covering, iron and unavoidable impurities.

The remainder of the covered electrode as a whole is components excluded in the steel core wire and the covering, unavoidable impurities of the steel core wire and the covering, and Fe of the steel core wire.

[0033]

[Metal carbonate having a particle diameter of 75 μm or less in metal carbonate: 50% to 80% by mass]

Further, in the low hydrogen-based covered electrode, the content of the metal carbonate having a particle diameter of 75 μm or less in the covering preferably ranges from 50% to 80% by mass based on the total mass of the metal carbonate.

[0034]

The particle size of the metal carbonate has an influence on the diffusible hydrogen amount and arc stability. When the content of the metal carbonate having a particle diameter of 75 μm or less is 50% or more, the diffusible hydrogen amount is decreased. On the other hand, when the content of the metal carbonate having a particle diameter of 75 μm or less is 80% by mass or less, arc stability can be kept better.

Thus, the content of the metal carbonate having a particle diameter of 75 μm or less in the whole of the metal carbonate preferably ranges from 50% to 80% by mass. From the viewpoint of more decreasing the diffusible hydrogen amount, the content of the metal carbonate having a particle diameter of 75 μm or less is more

preferably 55% by mass or more. Further, from the viewpoint of keeping arc stability better, it is more preferably 70% by mass or less.

[0035]

Measurement of the metal carbonate having a particle diameter of 75 μm or less can be performed by using a sieve shaker, specifically as shown below.

Using RPS-105 manufactured by Seishin Enterprise Co., Ltd., the metal carbonate having a particle diameter of 75 μm or less is separated through a sieve in accordance with JIS Z 8801-1:2006. In that case, as the sieving conditions, the sound wave frequency is 80 Hz, the pulse interval is 1 second, and the classification time is 2 minutes.

[0036]

The content of the metal carbonate having a particle diameter of 75 μm or less can be controlled to 50% to 80% by mass by using raw materials having different particle size distributions and changing the blending ratio thereof.

[0037]

Further, in the covered electrode, the value of the following equation (1) preferably ranges from 5 to 50.

$$(1.22 \times [\text{Na}] + 1.49 \times [\text{K}]) / [\text{Li}] \cdots (1)$$

wherein [Na] is a content (% by mass) of the Na compound on a Na basis in the covering, [K] is a content (% by mass) of the K compound on a K basis in the covering and [Li] is a content (% by mass) of the Li compound on a Li basis in the covering.

[0038]

[Value of Equation (1): 5 to 50]

The degrees of influence of the alkali components on the adhesion strength and moisture absorption resistance of the covering are considered to have a correlation with the atomic radii of the respective elements. When the atomic radius of Li is taken as 1, the atomic radius of Na is represented as 1.22, and the atomic radius of K is represented as 1.49. The adhesion strength and moisture absorption resistance of the covering can be evaluated at the same time by a parameter of the above-mentioned equation (1) in which Na and K are placed in the numerator and Li is placed in the denominator.

[0039]

When the value of the equation (1) is 5 or more, coating properties of the covering are improved. On the other hand, when the value of the equation (1) is 50 or less, moisture absorption resistance of the covering is improved. Thus, the value of the equation (1) preferably ranges from 5 to 50. From the viewpoint of more improving coating properties, the value of the equation (1) is more preferably 20 or more. Further, from the viewpoint of more improving moisture absorption resistance, it is more preferably 30 or less.

The equation (1) has been statistically determined from experimental results.

[0040]

[Coverage]

Although not particularly specified, the coverage of the covering on the covered electrode preferably ranges from 22% to 45% by mass. The coverage is calculated by “(the mass of the covering)/(the total mass of the electrode)×100”. When the coverage of the covering is 22% by mass or more, shielding of a molten pool is less likely to become insufficient, and the N amount and the diffusible hydrogen amount in the weld metal become liable to be decreased. For this reason, the toughness and cracking resistance of the weld metal tend to be improved. On the other hand, when the coverage is 45% by mass or less, arc would be liable to be more stabilized. The coverage as used herein is the ratio of the covering to the whole electrode after baking.

[0041]

[Method for Producing Low Hydrogen-based Covered Electrode]

The low hydrogen-based covered electrode in the present invention can be produced, for example, as shown below.

First, the above-mentioned covering is cover-coated around the above-mentioned steel core wire so as to give a coverage of 22% to 45% by mass by means of a binder such as water glass represented by sodium silicate or potassium silicate, using an ordinary electrode coating machine. Then, in order to remove water, baking is performed at 470 to 540°C.

The contents of the above-mentioned components of the covering are values of electrodes after cover-coating and baking (electrode products). Further, the coverage is the ratio of the covering based on the whole electrode after baking.

Examples

[0042]

The advantageous effects in the present invention will be described below with reference to examples within the scope of the present invention, as compared with comparative examples outside the scope of the present invention.

A covering was cover-coated around a steel core wire having a diameter of 4.0 mm so as to give a coverage ranging from 22% to 45% by mass based on the total mass of a covered electrode, using an ordinary electrode coating machine. Then, in order to remove water, baking was performed at 470 to 540°C. Thus, respective covered electrodes composed of the chemical components shown in Tables 1 and 2 were experimentally produced. The contents of the components of the covering are values of electrodes after cover-coating and baking (electrode product). Further, the coverage is the ratio of the covering based on the whole electrode after baking.

Welding was performed using the respective covered electrodes. Welding performance was evaluated, and the mechanical performance and diffusible hydrogen amount of weld metal obtained were evaluated. Further, moisture absorption resistance and adhesion of the coverings were evaluated. Re-drying in tests of mechanical performance, moisture absorption resistance and diffusible hydrogen amount was performed before the respective tests, and was not duplicately performed.

[0043]

In the tables, the underlined values are outside the scope of the present invention. Further, in Table 2, “tr.” indicates such a trace amount as to be undetectable. Further, in Table 2, the remainder of the components is components excluded by the conversion in the steel core wire and the covering, unavoidable impurities of the steel core wire and the covering, and Fe of the steel core wire.

[0044]

[Table 1]

Steel Core Wire	C	Si	Mn	P	S	N	Fe
A	<0.01	0.01	0.45	0.003	0.009	0.0050	Remainder
B	0.02	0.02	0.51	0.004	0.006	0.0041	Remainder
C	0.04	0.01	0.47	0.005	0.006	0.0030	Remainder

* Remainder includes unavoidable impurities, in addition to Fe.

[0045]

[Table 2]

No.	Steel Core Wire	Chemical Composition (% by mass)									
		Covering					Steel Core Wire + Covering				
		Metal Carbonate (CO ₂ basis)	Metal Fluoride (F basis)	TiO ₂	ZrO ₂	Al ₂ O ₃	Mo+Cr	C	Si+SiO ₂ (Si basis)	Mn	Ni
1	A	3.5	2.0	0.10	0.7	0.10	0.55	0.01	1.5	1.3	1.8
2	A	3.5	1.0	tr.	1.0	0.11	0.51	0.01	2.4	1.5	2.0
3	B	7.3	1.3	tr.	0.6	0.08	0.06	0.02	2.2	2.0	1.5
4	A	3.5	1.3	tr.	1.0	0.11	0.22	0.01	2.8	1.5	2.0
5	A	3.5	1.3	tr.	1.0	0.11	0.22	0.01	2.4	2.5	2.0
6	A	4.0	1.6	tr.	1.0	0.09	0.51	0.01	2.4	1.5	2.0
7	A	3.7	2.2	tr.	1.5	0.07	0.51	0.01	2.4	1.5	1.7
8	A	4.1	1.8	0.04	1.0	0.11	0.47	0.01	2.4	1.0	1.7
9	B	3.7	1.8	0.15	1.5	0.05	0.35	0.03	2.4	1.5	1.2
10	B	4.1	1.8	tr.	1.0	0.11	1.20	0.02	2.2	2.0	1.5
11	A	3.2	1.5	0.15	0.8	0.05	0.75	0.01	1.8	1.5	1.8
12	B	5.5	2.2	0.15	1.5	0.05	0.75	0.03	2.7	2.2	2.5
13	B	3.7	1.8	0.21	1.5	0.05	0.35	0.03	2.4	1.5	2.8
14	A	4.1	0.9	tr.	1.0	0.07	0.25	0.01	2.0	1.5	1.9
15	A	3.5	1.5	0.30	1.2	0.03	0.15	0.01	2.6	1.2	2.5
16	A	4.1	1.8	tr.	0.4	0.11	0.51	0.01	2.4	1.5	1.9
17	C	5.0	2.4	tr.	1.0	0.11	0.45	0.06	2.4	1.5	1.9
18	C	4.1	1.8	tr.	1.2	0.01	0.40	0.04	2.0	1.5	2.2
19	C	4.1	2.8	tr.	1.0	0.02	0.40	0.03	2.4	1.5	2.2
20	A	4.1	1.8	tr.	1.8	0.11	0.51	0.01	2.4	1.5	1.9
21	A	4.1	1.8	tr.	1.0	0.11	0.51	0.01	2.4	1.5	1.9
22	A	6.5	1.2	0.08	1.0	0.15	0.10	0.01	2.5	1.5	1.6

[Table 2 continued]

No.	Chemical Composition (% by mass)						Equation (1)
	Covering					Metal Carbonate	
	Li Compound (Li basis)	Na Compound (Na basis)	K Compound (K basis)	Na+K (total of bases)	Fe	Metal Carbonate (particle diameter $\leq 75\text{ }\mu\text{m}$)	
1	0.02	0.30	0.20	0.50	8.0	70	33
2	0.02	0.30	0.30	0.60	2.0	65	41
3	0.04	0.35	0.22	0.57	5.7	67	19
4	0.02	0.30	0.30	0.60	6.8	62	41
5	0.02	0.40	0.10	0.50	2.5	62	32
6	0.02	0.33	0.26	0.59	6.0	52	40
7	0.02	0.33	0.26	0.59	6.0	62	40
8	0.02	0.30	0.30	0.60	1.2	62	41
9	0.02	0.10	0.20	0.30	2.0	73	21
10	0.01	0.21	0.15	0.36	5.5	65	48
11	0.02	0.25	0.20	0.45	7.5	70	30
12	0.02	0.25	0.20	0.45	7.5	60	30
13	0.02	0.10	0.20	0.30	2.0	73	21
14	0.02	0.33	0.26	0.59	6.0	57	40
15	0.05	0.33	0.26	0.59	7.5	77	16
16	0.02	0.33	0.26	0.59	6.0	55	40
17	0.02	0.33	0.26	0.59	6.3	70	40
18	0.12	0.35	0.30	0.65	1.5	60	7
19	0.08	0.35	0.30	0.65	1.6	60	11
20	0.02	0.33	0.26	0.59	10.0	62	40
21	0.03	0.45	0.40	0.85	6.0	54	46
22	0.09	0.33	0.26	0.59	3.5	70	9

[Table 2 continued]

No.	Steel Core Wire	Chemical Composition (% by mass)									
		Covering					Steel Core Wire + Covering				
		Metal Carbonate (CO ₂ basis)	Metal Fluoride (F basis)	TiO ₂	ZrO ₂	Al ₂ O ₃	Mo+Cr	C	Si+SiO ₂ (Si basis)	Mn	Ni
23	A	3.7	2.2	tr.	1.5	0.07	0.51	0.01	2.4	1.5	1.7
24	A	4.0	2.2	tr.	1.5	0.07	0.45	0.01	2.4	1.5	1.7
25	A	4.0	2.2	tr.	1.5	0.07	0.51	0.01	2.7	1.5	2.0
26	A	4.0	2.2	tr.	1.5	0.07	0.45	0.01	2.7	1.5	2.0
27	A	4.1	1.8	tr.	1.0	0.11	0.51	0.01	2.4	1.5	1.9
28	A	4.1	1.8	tr.	1.0	0.11	0.51	0.01	2.4	1.5	1.9
29	A	3.2	1.0	tr.	<u>2.0</u>	0.05	0.15	0.01	2.0	1.1	1.5
30	C	4.0	2.0	0.15	1.5	<u>0.20</u>	0.50	<u>0.08</u>	2.0	1.1	1.5
31	A	3.5	2.0	0.15	<u>0.3</u>	0.05	0.40	0.01	2.5	<u>3.0</u>	2.0
32	B	3.5	<u>3.3</u>	0.15	1.5	0.05	<u>0.03</u>	0.02	2.4	1.5	2.0
33	A	<u>2.8</u>	1.2	0.20	1.3	0.03	0.40	0.01	<u>3.4</u>	1.2	1.4
34	A	5.5	1.8	0.20	1.6	0.12	0.55	0.01	2.8	2.0	<u>3.5</u>
35	B	<u>8.0</u>	2.0	tr.	1.5	0.05	<u>1.50</u>	0.02	2.3	1.8	1.6
36	A	4.0	1.8	tr.	1.0	0.05	0.55	0.01	2.2	1.7	<u>1.0</u>
37	B	5.2	1.6	tr.	0.7	0.03	0.43	0.02	2.1	<u>0.7</u>	2.3
38	A	3.8	<u>0.7</u>	0.15	1.0	0.10	0.33	0.01	2.5	2.2	2.6
39	A	4.2	1.9	<u>0.50</u>	1.4	0.08	0.50	0.01	2.0	1.8	2.4
40	B	5.2	1.4	0.25	0.6	0.02	0.26	0.02	<u>1.2</u>	1.9	1.6

Equation (1) is $(1.22 \times [\text{Na}] + 1.49 \times [\text{K}]) / [\text{Li}]$,
 wherein [Na] is a content (% by mass) of the Na compound on a Na basis in the covering, [K] is a content (% by mass) of the K compound on a K basis in the covering and [Li] is a content (% by mass) of the Li compound on a Li basis in the covering.

[Table 2 continued]

No.	Chemical Composition (% by mass)						Equation (1)
	Covering					Metal Carbonate	
	Li Compound (Li basis)	Na Compound (Na basis)	K Compound (K basis)	Na+K (total of bases)	Fe	Metal Carbonate (particle diameter $\leq 75 \mu\text{m}$)	
23	0.02	0.33	0.26	0.59	6.0	45	40
24	0.02	0.33	0.26	0.59	6.0	84	40
25	0.02	0.45	0.40	0.85	8.0	60	57
26	0.11	0.15	0.20	0.35	6.0	75	4
27	0.006	0.10	0.20	0.30	5.8	75	70
28	0.14	0.20	0.25	0.45	6.0	75	4
29	0.03	0.35	0.26	0.61	1.5	62	27
30	0.03	0.25	0.25	0.50	12.0	60	23
31	0.02	0.33	0.26	0.59	6.0	70	40
32	0.02	0.25	0.40	0.65	6.0	65	45
33	0.02	0.25	0.40	0.65	5.0	65	45
34	0.03	0.33	0.26	0.59	6.5	70	26
35	0.02	0.25	0.20	0.45	5.5	60	30
36	0.10	0.25	0.20	0.45	1.0	70	6
37	0.02	0.10	0.15	0.25	4.1	55	17
38	0.02	0.45	0.50	0.95	8.0	60	65
39	0.03	0.45	0.40	0.85	8.8	45	38
40	0.07	0.25	0.25	0.50	7.8	84	10

Equation (1) is $(1.22 \times [\text{Na}] + 1.49 \times [\text{K}]) / [\text{Li}]$,
 wherein [Na] is a content (% by mass) of the Na compound on a Na basis in the covering, [K] is a content (% by mass) of the K compound on a K basis in the covering and [Li] is a content (% by mass) of the Li compound on a Li basis in the covering.

[0046]

Evaluation criteria of respective test are as follows.

<Mechanical Performance>

Mechanical performance of the weld metal was evaluated by the method in accordance with JIS Z 3111:2005. JIS G 3106:2008 SM490A (plate thickness: 20 mm) was used as a steel plate (base material) for welding. The groove shape was a 20°-angle V-shaped groove, and the root gap was 16 mm. The welding position was a flat position, the polarity was DCEP (Direct Current Electrode Plus), the welding current was from 150 to 160 A, the arc voltage was from 22 to 23 V, the welding heat input was from 2.0 to 2.1 kJ/mm, and the preheating-interpass temperature was from 90 to 110°C. The electrode was heated under a temperature condition of 350°C for 1 hour before welding, for re-drying of the covering.

For the mechanical performance, the strength of the weld metal was evaluated by the 0.2% yield strength, and the toughness of the weld metal was evaluated by absorbed energy (vE -60°C) of a Charpy impact test at -60°C. Then, one having a 0.2% yield strength of from 690 to 900 MPa and an absorbed energy of 69 J or more was evaluated as good.

[0047]

<Welding Performance>

Welding performance was evaluated in welding when evaluating the mechanical performance. The welding performance was evaluated by arc stability, slag detachability and the bead shape. Each was organoleptically evaluated on a five-point scale of 1 to 5, and 3 or more was judged as good.

For the bead shape, smoothness of the bead was evaluated, and for the slag detachability, it was evaluated whether or not the slag was easily detached when removed with an air chipper, after welding.

[0048]

<Moisture Absorption Resistance of Covering>

Moisture absorption resistance of the covering was evaluated by exposing the covered electrode re-dried by heating under a temperature condition of 350°C for 1 hour, in an atmosphere of a temperature of 30°C and a relative humidity of 80% for 6 hours, and measuring the amount of water absorbed by the covering, by a Karl Fischer

method (vaporizing method). In order to vaporize water from the covering at the time of measurement, heating was performed at 750°C, and dry air was introduced to a measuring device as a carrier gas. As a result, one having an amount of water in the covering (noted as KF moisture absorption in the table) of 3000 ppm by mass or less was judged as good.

[0049]

<Adhesion of Covering>

For adhesion of the covering, first, after baking, the presence or absence of cracks on a surface of the covering was visually observed, and thereafter, stability of a protective sheath during welding was organoleptically evaluated on a five-point scale of 1 to 5. As a result, 3 or more was judged as good.

[0050]

<Diffusible Hydrogen Amount>

The diffusible hydrogen amount in the weld metal was measured by the method in accordance with JIS Z 3118:2007. In a flat welding position, taking the polarity as DCEP (Direct Current Electrode Plus), one-pass welding was performed under conditions of a welding current of 150 to 160 A, an arc voltage of 22 V and a welding speed of 180 mm/min. In that case, for a welding atmosphere, the temperature was 20°C, and the humidity was 10% RH. Before welding, each electrode was heated under a temperature condition of 350°C for 1 hour, for re-drying of the covering.

The diffusible hydrogen amount in the weld metal obtained by welding was measured. As a result, one having a diffusible hydrogen amount (noted as [H]D in the table) of 3.0 mL/100 g or less was judged as good.

[0051]

The measurement results are shown in Table 3. In the table, the underlined values do not satisfy the evaluation criteria.

[0052]

[Table 3]

No.	Strength	Toughness	Diffusible Hydrogen Amount	Moisture Absorption Resistance	Arc Stability	Slag Detachability	Bead Shape	Adhesion	Others
	0.2% Yield Strength (MPa)	$\nu E -60^{\circ}C$ (J)	[H]D (mL/100 g)	KF Moisture Absorption (ppm)					
1	751	73	2.4	1865	4	4	4	3	
2	760	72	2.6	2510	4	4	4	4	
3	697	100	1.5	850	3	4	4	4	
4	733	103	2.3	2455	4	3	3	4	
5	852	75	2.5	1650	4	4	4	4	
6	755	105	2.8	2431	4	4	4	4	
7	768	99	1.6	2275	4	4	4	4	
8	720	74	1.8	2631	4	4	4	4	
9	725	71	1.5	832	3	4	4	3	
10	885	72	2.6	2930	4	4	4	4	
11	782	80	2.8	1723	4	5	4	4	
12	875	70	2.2	1873	3	4	4	4	
13	785	82	1.4	811	3	4	4	3	
14	721	115	1.9	2210	4	4	3	4	
15	714	72	1.7	750	3	4	4	4	
16	748	110	2.0	2056	4	4	3	4	
17	848	71	1.9	2017	4	4	4	4	
18	778	75	1.4	723	4	4	4	3	
19	760	83	1.5	744	3	4	4	3	
20	750	108	1.6	2320	3	3	4	4	
21	748	95	2.7	2945	5	4	4	5	

[Table 3 continued]

No.	Strength	Toughness	Diffusible Hydrogen Amount	Moisture Absorption Resistance	Arc Stability	Slag Detachability	Bead Shape	Adhesion	Others
	0.2% Yield Strength (MPa)	vE -60°C (J)	[H]D (mL/100 g)	KF Moisture Absorption (ppm)					
22	710	90	1.7	763	4	3	4	3	
23	772	95	2.9	2602	5	4	4	4	
24	754	100	1.6	2570	3	4	4	4	
25	805	82	2.9	2930	4	4	4	5	
26	780	102	1.3	655	4	4	4	3	
27	760	100	2.8	<u>3250</u>	3	4	4	4	
28	758	95	1.3	635	4	4	4	2	
29	711	70	2.8	2860	4	2	4	4	
30	<u>921</u>	<u>58</u>	2.1	905	3	1	4	4	
31	<u>915</u>	69	1.8	1985	4	4	2	4	
32	<u>675</u>	85	2.7	2872	2	4	4	4	
33	705	<u>65</u>	<u>4.1</u>	2901	4	2	1	5	
34	876	73	2.7	1058	3	3	4	4	Hot cracking occurred
35	<u>930</u>	<u>62</u>	2.4	1841	2	4	4	4	
36	823	<u>65</u>	1.7	752	4	4	4	3	Deposition rate was decreased
37	725	70	2.1	805	2	4	4	2	Blowholes occurred
38	789	82	2.9	<u>3557</u>	4	4	2	5	
39	802	<u>61</u>	2.9	2568	5	4	4	4	
40	701	<u>67</u>	2.0	715	3	5	4	1	

[0053]

As shown in Table 3, Test Nos. 1 to 26 (examples) within the scope of the present invention have provided good results in all evaluation items.

On the other hand, Test Nos. 27 to 40 (comparative examples) outside the scope of the present invention have provided the following results.

[0054]

In No. 27, moisture absorption resistance of the covering was poor, because the Li content in the covering was less than the lower limit value.

In No. 28, adhesion of the covering was poor, because the Li content in the covering exceeded the upper limit value.

In No. 29, slag detachability was poor, because the ZrO_2 content in the covering exceeded the upper limit value.

[0055]

In No. 30, slag detachability was poor, because the Al_2O_3 content in the covering exceeded the upper limit value. Further, the strength was excessively increased and the toughness was poor, because the C content in the “steel core wire + covering” exceeded the upper limit value.

In No. 31, the bead shape was poor, because the ZrO_2 content in the covering was less than the lower limit value. Further, the strength was excessively increased, because the Mn content in the “steel core wire + covering” exceeded the upper limit value.

In No. 32, arc stability was poor, because the content of the metal fluoride in the covering exceeded the upper limit value. Further, the strength was poor, because the total of the Mo content and the Cr content in the “steel core wire + covering” was less than the lower limit value.

[0056]

In No. 33, the diffusible hydrogen amount was high and the toughness was poor, because the content of the metal carbonate in the covering was less than the lower limit value. Further, slag detachability and the bead shape were poor, because the total of the Si content and the SiO_2 content in the “steel core wire + covering” exceeded the upper limit value.

In No. 34, hot cracking occurred, because the Ni content in the “steel core wire + covering” exceeded the upper limit value.

In No. 35, arc stability was poor, because the content of the metal carbonate in the covering exceeded the upper limit value. Further, the strength was excessively increased and the toughness was poor, because the total of the Mo content and the Cr content in the “steel core wire + covering” exceeded the upper limit value.

[0057]

In No. 36, the toughness was poor, because the Ni content in the “steel core wire + covering” was less than the lower limit value. Further, the deposition rate was decreased, because the Fe content in the covering was less than the lower limit value.

In No. 37, blowholes occurred, because the Mn content in the “steel core wire + covering” was less than the lower limit value. Further, arc stability and adhesion of the covering were poor, because the total of the Na content and the K content in the covering was less than the lower limit value.

In No. 38, the bead shape was poor, because the content of the metal fluoride in the covering was less than the lower limit value. Further, moisture absorption resistance of the covering was poor, because the total of the Na content and the K content in the covering exceeded the upper limit value.

[0058]

In No. 39, the toughness was poor, because the TiO_2 content in the covering exceeded the upper limit value.

In No. 40, the toughness was poor, because the total of the Si content and the SiO_2 content in the “steel core wire + covering” was less than the lower limit value. Further, adhesion of the covering was deteriorated due to deterioration of coating properties.

[0059]

Although the present invention has been described in detail with reference to the embodiments and the examples, the gist of the present invention is not limited to the above-mentioned contents, and the scope of rights of the present invention should be broadly interpreted on the basis of the claims. It goes without saying that the contents of the present invention may be broadly modified or altered on the basis of the above-mentioned description.

CLAIMS

1. A low hydrogen-based covered electrode comprising a steel core wire coated with a covering,

wherein the covering contains, based on a total mass of the low hydrogen-based covered electrode,

a metal carbonate: 3.0% to 7.5% by mass on a CO₂ basis,

a metal fluoride: 0.9% to 3.0% by mass on a F basis,

TiO₂ ≤ 0.30% by mass,

ZrO₂: 0.4% to 1.8% by mass,

Al₂O₃ ≤ 0.15% by mass,

a Li compound: 0.01% to 0.12% by mass on a Li basis, and

a total of a Na compound on a Na basis and a K compound on a K basis: 0.30% to 0.90% by mass, and

the low hydrogen-based covered electrode contains, based on the total mass of the low hydrogen-based covered electrode,

a total of Mo and Cr: 0.06% to 1.20% by mass,

C ≤ 0.06% by mass,

a total of Si and SiO₂: 1.5% to 3.0% by mass on a Si basis,

Mn: 0.9% to 2.7% by mass, and

Ni: 1.2% to 3.0% by mass.

2. The low hydrogen-based covered electrode according to claim 1, wherein the covering contains 1.2% by mass or more and 10.0% by mass or less of Fe based on the total mass of the low hydrogen-based covered electrode.

3. The low hydrogen-based covered electrode according to claim 1, wherein the metal carbonate contains a metal carbonate having a particle diameter of 75 μm or less in an amount of from 50% to 80% by mass based on a total mass of the metal carbonate.

4. The low hydrogen-based covered electrode according to claim 2, wherein the metal carbonate contains a metal carbonate having a particle diameter of 75 μm or less in an amount of from 50% to 80% by mass based on a total mass of the metal carbonate.

5. The low hydrogen-based covered electrode according to any one of claims 1 to 4, wherein a value of the following equation (1) is from 5 to 50.

$$(1.22 \times [\text{Na}] + 1.49 \times [\text{K}]) / [\text{Li}] \cdots (1)$$

wherein [Na] is a content (% by mass) of the Na compound on a Na basis in the covering, [K] is a content (% by mass) of the K compound on a K basis in the covering and [Li] is a content (% by mass) of the Li compound on a Li basis in the covering.