

DESCRIPTION

TITLE OF INVENTION

FLUX-CORED WIRE FOR GAS SHIELD ARC WELDING

5

TECHNICAL FIELD

[0001]

The present invention relates to a flux-cored wire for gas shielded arc welding.

10 BACKGROUND ART

[0002]

In general, a smoke exhaust facility of boilers for burning fossil fuel such as heavy oil or coal, gas fuel such as liquefied natural gas, general waste such as municipal waste, industrial waste such as wood waste, fiber waste, waste oil, plastic, waste tires, and medical waste, sewage sludge, or the like is exposed to sulfur trioxide and hydrogen chloride in exhaust gas, and is used in an environment in which sulfuric acid dew point corrosion or hydrochloric acid dew point corrosion is likely to occur.

In addition, hydrochloric acid dew point corrosion is likely to occur even in a steel plating pickling tank for housing a pickling solution such as hydrochloric acid, due to exposure to hydrochloric acid for a long time. Therefore, corrosion resistant steel is used as a material of a welded structure used in a sulfuric acid and hydrochloric acid environment, such as a flue duct of a boiler, a casing, a heat exchanger, a basket material and heat transfer element plate of a rotary regenerative air preheater, a temperature reduction tower, a bag filter, a smoke exhaust facility such as a chimney, and a steel plating pickling tank.

25 [0003]

The welded structure is generally produced by welding and joining steel materials to each other, but when there is a difference in corrosion resistance between a weld metal and a base metal, one having poor corrosion resistance is selectively corroded, and a life of the structure is significantly shortened. In addition, when the weld metal is selectively corroded, stress concentration occurs in a corrosion hole, and the welded structure may be broken in an extreme case. As described above, in the use of the welded structure, it is necessary to sufficiently ensure corrosion resistance of not only the base metal but also a weld in the case of an application in which corrosion deterioration cannot be ignored.

30

[0004]

As a welding material dedicated to sulfuric acid dew point corrosion resistant steel, a material containing Cu alone as a corrosion resistant element or a material containing Cu-Cr is common. However, weld metals obtained by using these welding materials exhibit sufficiently excellent corrosion resistance in a sulfuric acid dew point corrosion environment seen in a plant smoke exhaust device of a heavy oil burning boiler, but sufficient corrosion resistance cannot be obtained because sulfuric acid dew point corrosion and hydrochloric acid dew point corrosion occur at the same time in a coal-fired boiler, a waste incineration facility, a waste gasification melting facility, or the like.

[0005]

Therefore, in order to improve the sulfuric acid dew point corrosion resistance and hydrochloric acid dew point corrosion resistance of a weld metal, a flux-cored wire in which 0.01 to 0.5 mass% of Sb is contained in one or both of a steel sheath and a filling flux has been proposed (see Patent Literature 1). Patent Literature 1 describes that Sb is an element that improves sulfuric acid resistance and hydrochloric acid resistance by coexisting with Cu.

CITATION LIST

PATENT LITERATURE

[0006]

Patent Literature 1: JP 2004-90042 A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0007]

However, since Sb is an element that induces surface cracking similarly to Cu, surface cracking of the weld metal may occur when a content of Sb in the wire is increased in order to improve the hydrochloric acid resistance. In a case where Sb is added to the flux and an average grain diameter of Sb added is not controlled, arc stability during welding work decreases and viscosity of slag decreases, and production stability decreases due to segregation of Sb in the flux.

Therefore, it is required to develop a flux-cored wire which does not require control of the average grain diameter of Sb in the flux and by which a weld metal having good hydrochloric acid dew point corrosion resistance can be obtained even in a case where the

content of Sb in the wire is controlled to a lower range as compared with the related art.

[0008]

The present invention has been made in view of the above circumstances, and an object of the present invention is to provide a flux-cored wire for gas shielded arc welding, which is suitable for welding of a hydrochloric acid dew point corrosion resistant steels and can give a weld metal having excellent hydrochloric acid corrosion resistance.

SOLUTION TO PROBLEM

[0009]

The flux-cored wire for gas shielded arc welding in an aspect of the present invention is a flux-cored wire for gas shielded arc welding, which has a steel sheath filled with a flux, the flux-cored wire comprising,

relative to a total mass of the wire:

C: 0.02 mass% or more and 0.10 mass% or less;

Si: 0.05 mass% or more and 1.00 mass% or less;

Mn: 1.5 mass% or more and 3.0 mass% or less;

S: 0.003 mass% or more and 0.030 mass% or less;

Cu: 0.05 mass% or more and 0.50 mass% or less;

Ni: 0.05 mass% or more and 0.50 mass% or less;

Mo: 0.05 mass% or more and 0.35 mass% or less;

Co: 0.005 mass% or more and 0.300 mass% or less; and

Sb: 0.01 mass% or more and 0.20 mass% or less,

wherein a content of P is restricted to 0.030 mass% or less,

a content of Cr is restricted to 0.05 mass% or less, and

the following relationship (1) is satisfied:

$$57 \times [\text{Mo}] + 221 \times [\text{Co}] \geq 15 \quad (1)$$

wherein [Mo] represents the content (mass%) of Mo in the steel sheath and flux relative to the total mass of the wire, and [Co] represents the content (mass%) of Co in the steel sheath and flux relative to the total mass of the wire.

[0010]

The flux-cored wire for gas shielded arc welding preferably further comprises Ti in an amount of 2.0 mass% or more and 4.5 mass% or less relative to the total mass of the wire.

[0011]

The flux-cored wire for gas shielded arc welding preferably further comprises a slag forming agent, and a total content of Na, K, Li, Mg, and F in the slag forming agent is preferably 0.010 mass% or more and 1.500 mass% or less relative to the total mass of the wire.

5 [0012]

The flux-cored wire for gas shielded arc welding preferably further comprises at least one kind selected from Nb, Zr, and V, and a total content of Nb, Zr, and V is preferably more than 0 mass% and 0.50 mass% or less relative to the total mass of the wire.

[0013]

10 The flux-cored wire for gas shielded arc welding preferably further comprises B in an amount of more than 0 mass% and 0.0080 mass% or less relative to the total mass of the wire.

ADVANTAGEOUS EFFECTS OF INVENTION

15 [0014]

The present invention can provide a flux-cored wire for gas shielded arc welding, which is suitable for welding of a hydrochloric acid dew point corrosion resistant steel and can give a weld metal having excellent hydrochloric acid corrosion resistance.

20 BRIEF DESCRIPTION OF DRAWINGS

[0015]

[FIG. 1A] FIG. 1A is a schematic diagram showing a location of a test piece of a welded joint subjected to a hydrochloric acid corrosion resistance test.

25 [FIG. 1B] FIG. 1B is a schematic diagram showing a location of a reference test piece subjected to a hydrochloric acid corrosion resistance test.

DESCRIPTION OF EMBODIMENTS

[0016]

30 Hereinafter, embodiments for carrying out the present invention (the present embodiments) are described in detail. It should be noted that the present invention is not limited to the embodiments described below, and can be optionally changed without departing from the scope of the present invention.

[0017]

The present inventors have intensively studied a flux-cored wire for gas shielded arc welding (hereinafter, also simply referred to as “wire” or the like) by which a weld metal having excellent hydrochloric acid corrosion resistance can be obtained by controlling the content of Sb causing surface cracking of a weld metal to a low range even in a case where an average grain diameter of Sb is not required to be controlled. As a result, the present inventors have found that the hydrochloric acid corrosion resistance of the weld metal is effectively improved by allowing the wire to contain each of Mo and Co in an appropriate content and controlling a ratio between Mo and Co to a predetermined range.

[0018]

That is, in the flux-cored wire in the present embodiment, chemical components are contained in predetermined contents, respectively, relative to the total mass of the wire, and a content of a part of the chemical components satisfies a predetermined relationship. Hereinafter, the flux-cored wire in the present embodiment is described.

[0019]

[Flux-cored wire]

The flux-cored wire in the present embodiment is a wire in which a steel sheath (hoop) is filled with a flux. Specifically, the flux-cored wire in the present embodiment includes a steel sheath having a cylindrical shape and a flux with which an interior (inside) of the steel sheath is filled. The flux-cored wire may be in any form of a seamless type having no seam in the sheath, and a seam type having a seam in the sheath, such as a C cross section or an overlapped cross section. The surface (outside of the sheath) of the flux-cored wire may or may not be plated with Cu or the like.

[0020]

A thickness of a steel sheath and wire diameter (diameter) of the flux-cored wire in the present embodiment are not particularly limited, and from the viewpoint of wire feeding stability, the wire diameter is preferably 0.8 mm to 4.0 mm, and the wire diameter is more preferably 1.2 mm to 2.4 mm.

[0021]

Next, regarding the composition of the flux-cored wire in the present embodiment, the reason for adding components and the reason for limiting the composition are described in detail. Each element for obtaining the weld metal having the required properties may be added to at least one of a steel sheath and a filling flux. Therefore, unless otherwise specified in the following description, the amount of each component in the flux-cored wire is

specified by the total amount of the components contained in the steel sheath and the flux, relative to the total mass of the wire (the total amount of the steel sheath and the flux inside the sheath).

[0022]

5 The elements described below are added to the steel sheath or the flux in various forms such as oxides, simple substances, compounds, or alloys, and the form of elements to be added is not particularly specified in the present embodiment and the origin of raw materials does not matter in the present embodiment. Therefore, the content of the elements described below is a total amount of values obtained by converting the amounts of elements
10 in various forms such as simple substances, oxides, compounds and alloys to the amount of the elements in the form of simple substance.

[0023]

<C: 0.02 mass% or more and 0.10 mass% or less>

15 C is an element that improves the strength of a weld metal but also increases the hot cracking susceptibility of the weld metal.

In the case where the content of C is less than 0.02 mass%, the amount of C dissolved in the weld metal is insufficient and the strength is not improved. Therefore, the content of C in the steel sheath and the flux is 0.02 mass% or more, and preferably 0.03 mass% or more.

20 On the other hand, in the case where the content of C is more than 0.10 mass%, the amount of C dissolved in the weld metal is excessive and the hot cracking susceptibility is high. Therefore, the content of C in the steel sheath and the flux is 0.10 mass% or less, and preferably 0.08 mass% or less.

25 Examples of the C source include, in addition to those added to the steel sheath, iron powder or alloy powder having a large amount of carbon, carbon single phase such as graphite, plumbago, and carbon nanotube, and organic substances such as starch and corn starch, which are added to the flux.

[0024]

<Si: 0.05 mass% or more and 1.00 mass% or less>

30 Si is an essential element for deoxidizing the weld metal.

In the case where the content of Si is less than 0.05 mass%, the amount of Si dissolved in the weld metal is insufficient and the deoxidizing effect cannot be sufficiently obtained, and therefore, the content of Si in the steel sheath and the flux is 0.05 mass% or

more, and preferably 0.20 mass% or more.

On the other hand, in the case where the content of Si is more than 1.00 mass%, the hot cracking susceptibility increases. Therefore, in order to reduce the hot cracking susceptibility, it is necessary to add alloy elements in the weld metal, such as Mn and Ni, to the wire. However, in the case where the hot cracking susceptibility is reduced by the addition of Mn, Ni, or the like, the toughness of the weld metal decreases and the cold cracking susceptibility caused by hydrogen in the weld metal increases. Therefore, the content of Si in the steel sheath and the flux is 1.00 mass% or less, and preferably 0.90 mass% or less.

Si may be added to the flux as a Si oxide such as SiO_2 , or may be added to the wire in the form of a Fe-Si alloy, a Si metal, or the like. In the present embodiment, the content of each of the Si oxide, the Si metal, and the Si alloy is specified as a value in terms of Si, and the converted value is simply referred to as the content of Si.

[0025]

<Mn: 1.5 mass% or more and 3.0 mass% or less>

Mn deoxidizes the weld metal and improves the strength and toughness of the weld metal. A compound is formed by Mn and S that increases the hot cracking susceptibility, so that Mn is an essential element for preventing hot cracking.

In the case where the content of Mn is less than 1.5 mass%, the amount of Mn dissolved in the weld metal is insufficient and the effect of preventing deoxidation and hot cracking is not sufficiently obtained, and the strength and toughness are not improved. Therefore, the content of Mn in the steel sheath and the flux is 1.5 mass% or more, and preferably 1.8 mass% or more.

On the other hand, in the case where the content of Mn is more than 3.0 mass%, the amount of Mn dissolved in the weld metal is excessive, the toughness of the weld metal decreases, and the cold cracking susceptibility caused by hydrogen in the weld metal increases. Therefore, the content of Mn in the steel sheath and the flux is 3.0 mass% or less, and preferably 2.8 mass% or less.

Mn may be added to the flux as a Mn oxide such as MnO or MnO_2 , or may be added to the wire in the form of a Fe-Mn alloy, a Mn metal, or the like. In the present embodiment, the content of each of the Mn oxide, the Mn metal, and the Mn alloy is specified as a value in terms of Mn, and the converted value is simply referred to as the content of Mn.

[0026]

<S: 0.003 mass% or more and 0.030 mass% or less>

S is an element that improves the flow of droplets during welding, but is also an element that causes decrease in toughness of the weld metal and increase in hot cracking susceptibility.

5 In the case where the content of S is less than 0.003 mass%, the viscosity of the droplets during welding increases and the flow of the droplets is inhibited. Therefore, the content of S in the steel sheath and the flux is 0.003 mass% or more, and preferably 0.004 mass% or more.

10 On the other hand, in the case where the content of S is more than 0.030 mass%, the amount of S dissolved in the weld metal is excessive, the toughness of the weld metal decreases, and the hot cracking susceptibility increases. Therefore, the content of S in the steel sheath and the flux is 0.030 mass% or less, and preferably 0.025 mass% or less.

Examples of the S source include, in addition to those added to the steel sheath, sulfides such as iron sulfide and copper sulfide, and sulfates, which are added to the flux.

15 Furthermore, examples of the S source also include an S compound applied to the wire surface.

[0027]

<Cu: 0.05 mass% or more and 0.50 mass% or less>

Cu is an element that improves the corrosion resistance of the weld metal.

20 In the case where the content of Cu is less than 0.05 mass%, the amount of Cu dissolved in the weld metal is insufficient, and the effect of improving the corrosion resistance of the weld metal cannot be obtained. Therefore, the content of Cu in the steel sheath and the flux is 0.05 mass% or more, and preferably 0.10 mass% or more.

25 On the other hand, in the case where the content of Cu is more than 0.50 mass%, the amount of Cu dissolved in the weld metal is excessive, and the hot cracking susceptibility of the weld metal increases. Therefore, the content of Cu in the steel sheath and the flux is 0.50 mass% or less, and preferably 0.40 mass% or less.

30 Cu is added to the wire mainly in the form of a Fe-Cu alloy, a Cu metal, or the like, but may be added to the flux as a Cu oxide such as Cu₂O or CuO. In the present embodiment, the content of each of the Cu alloy, the Cu metal, and the Cu oxide is specified as a value in terms of Cu, and the converted value is simply referred to as the content of Cu.

[0028]

<Ni: 0.05 mass% or more and 0.50 mass% or less>

Ni is an element that reduces the hot cracking susceptibility of the weld metal and improves the corrosion resistance.

In the case where the content of Ni is less than 0.05 mass%, the amount of Ni dissolved in the weld metal is insufficient, and the effect of preventing hot cracking of the weld metal and the effect of improving corrosion resistance cannot be sufficiently obtained. Therefore, the content of Ni in the steel sheath and the flux is 0.05 mass% or more, and preferably 0.10 mass% or more.

On the other hand, in the case where the content of Ni is more than 0.50 mass%, the amount of Ni dissolved in the weld metal is excessive, the hot cracking susceptibility increases, the strength of the weld metal increases, and the hydrogen cracking susceptibility increases. Therefore, the content of Ni in the steel sheath and the flux is 0.50 mass% or less, and preferably 0.40 mass% or less.

Examples of the Ni source include, in addition to those added to the steel sheath, a single metal and an alloy powder, which are added to the flux.

[0029]

<Mo: 0.05 mass% or more and 0.35 mass% or less>

Mo is an element that remarkably improves hydrochloric acid resistance of the weld metal together with Co and Cu, and this effect is further increased by the combined addition with Cu-Sb.

In the case where the content of Mo is less than 0.05 mass%, the effect of improving the hydrochloric acid resistance of the weld metal cannot be sufficiently obtained. Therefore, the content of Mo in the steel sheath and the flux is 0.05 mass% or more, preferably 0.10 mass% or more, and more preferably 0.12 mass% or more.

On the other hand, in the case where the content of Mo is more than 0.35 mass%, the tensile strength of a deposited metal increases. Therefore, the content of Mo in the steel sheath and the flux is 0.35 mass% or less, preferably 0.30 mass% or less, and more preferably 0.28 mass% or less. The optimum addition amount of Mo is 0.15 mass%.

[0030]

<Co: 0.005 mass% or more and 0.300 mass% or less>

Co is an element that significantly improves hydrochloric acid resistance of the weld metal by combined addition with Mo and Cu, and improves toughness as seen in the properties of nickel-cobalt-molybdenum steel (Ni-Co-Mo).

In the case where the content of Co is less than 0.005 mass%, the effect of

improving the hydrochloric acid resistance and toughness of the weld metal cannot be sufficiently obtained. Therefore, the content of Co in the steel sheath and the flux is 0.005 mass% or more, preferably 0.010 mass% or more, and more preferably 0.020 mass% or more.

On the other hand, in the case where the content of Co is more than 0.300 mass%, the tensile strength of the deposited metal is too high. Therefore, the content of Co in the steel sheath and the flux is 0.300 mass% or less, preferably 0.250 mass% or less, and more preferably 0.200 mass% or less. The optimum addition amount of Co is 0.050 mass%.

[0031]

<Relationship between content of Mo and content of Co: $57 \times [\text{Mo}] + 221 \times [\text{Co}] \geq 15$ >

The present inventors have performed gas shielded arc welding using flux-cored wires containing Mo and Co at various ratios, analyzed chemical components of the obtained weld metal, and performed regression analysis of the relation between the analysis value and the corrosion rate ratio of the weld metal. As a result, the present inventors have found an index for obtaining a weld metal having excellent hydrochloric acid resistance, which is realized by satisfying the following relationship (1) using the content of Mo and the content of Co in the wire as parameters.

$$57 \times [\text{Mo}] + 221 \times [\text{Co}] \geq 15 \quad (1)$$

Here, [Mo] represents the content (mass%) of Mo in the steel sheath and the flux relative to the total mass of the wire, and [Co] represents the content (mass%) of Co in the steel sheath and the flux relative to the total mass of the wire.

[0032]

In the case where a value calculated by the left side of the above relationship (1) is less than 15, a weld metal having excellent hydrochloric acid resistance cannot be obtained. Therefore, the content of Mo and the content of Co are controlled to fall within the predetermined ranges such that the value calculated by the left side of the relationship (1) is 15 or more. The value calculated by the left side of the relationship (1) is preferably 16 or more, more preferably 18 or more, and still more preferably 20 or more. On the other hand, in consideration of the balance with the strength of the weld metal, the value calculated by the left side of the relationship (1) is preferably 86 or less, more preferably 72 or less, and still more preferably 60 or less.

[0033]

<Sb: 0.01 mass% or more and 0.20 mass% or less>

Sb is an element that further improves sulfuric acid resistance and hydrochloric acid

resistance by coexisting with Cu.

In the case where the content of Sb is less than 0.01 mass%, sufficient corrosion resistance may not be obtained. Therefore, the content of Sb in the steel sheath and the flux is 0.01 mass% or more, and preferably 0.05 mass% or more.

5 On the other hand, in the case where the content of Sb is more than 0.20 mass%, surface cracking and segregation may occur. Therefore, the content of Sb in the steel sheath and the flux is 0.20 mass% or less, and preferably 0.15 mass% or less.

[0034]

<P: 0.030 mass% or less (including 0 mass%)>

10 Since P is an element that is present in the wire as an inevitable impurity and reduces the toughness of the weld metal, it is preferable to reduce the content of P as much as possible.

In the case where the content of P is more than 0.030 mass%, the amount of P dissolved in the weld metal is excessive, and the toughness of the weld metal may decrease.

15 Therefore, the content of P in the steel sheath and the flux is restricted to 0.030 mass% or less.

[0035]

<Cr: 0.05 mass% or less (including 0 mass%)>

20 Cr is an element that improves corrosion resistance particularly in an oxidative sulfuric acid dew point corrosion environment seen in a plant having a high sulfur oxide content in an exhaust gas, but inhibits the hydrochloric acid resistance, and therefore, it is preferable to reduce the content of Cr as much as possible.

In the case where the content of Cr is more than 0.05 mass%, the hydrochloric acid resistance may decrease. Therefore, the content of Cr in the steel sheath and the flux is restricted to 0.05 mass% or less.

25 [0036]

<Ti: 2.0 mass% or more and 4.5 mass% or less>

30 The flux-cored wire in the present embodiment preferably further contains, as an optional component, Ti in an amount of 2.0 mass% or more and 4.5 mass% or less. Ti is an element that improves the stability of the arc during welding and slag covering property, and improves the weldability in all positions. In addition, in a case where the metal Ti is added to the wire, the metal Ti has a function of deoxidizing the weld metal.

In the case where the content of Ti is 2.0 mass% or more, the effects of improving the stability of the arc during welding and the slag covering property are obtained.

Therefore, in the case where Ti is contained in the steel sheath and the flux, the content of Ti is preferably 2.0 mass% or more, more preferably 2.5 mass% or more, still more preferably 2.8 mass% or more, and yet still more preferably 3.0 mass% or more.

Ti is mainly added to the flux as a Ti oxide such as TiO_2 , but may be added to the wire in the form of a Fe-Ti alloy, a Ti metal, or the like. In the present embodiment, the content of each of the Ti oxide, the Ti metal, and the Ti alloy is specified as a value in terms of Ti, and the converted value is simply referred to as the content of Ti.

[0037]

<Total of Na, K, Li, Mg, and F in slag forming agent: 0.010 mass% or more and 1.500 mass% or less>

The flux-cored wire in the present embodiment preferably further contains a slag forming agent as an optional component. The slag forming agent is a component having an action of removing impurities (oxygen or the like) in the weld metal, and in the present embodiment, it is preferable that at least one slag forming agent is contained in the wire.

The kinds of the slag forming agent contained in the wire are not particularly limited to specific kinds, and usable examples thereof include alkali metals and alkaline earth metals, such as Na, K, Li, and Mg, and compounds thereof, oxides such as SiO_2 , ZrO_2 , Al_2O_3 , MnO , and MgO , fluorides such as CaF_2 , BaF_2 , MgF , and LiF , and carbonates such as CaCO_3 and BaCO_3 .

[0038]

In the case where the total content of Na, K, Li, Mg, and F in the slag forming agent is 0.010 mass% or more, the arc stability during welding is improved. Therefore, the total content of these elements relative to the total mass of the wire is preferably 0.010 mass% or more, more preferably 0.020 mass% or more, and still more preferably 0.030 mass% or more.

On the other hand, in the case where the total content is 1.500 mass% or less, the moisture content in the wire can be maintained at a low level, and the occurrence of hydrogen cracking can be prevented. Therefore, the total content of these elements relative to the total mass of the wire is preferably 1.500 mass% or less, and more preferably 1.000 mass% or less.

[0039]

<Total of at least one kind selected from Nb, Zr, and V: more than 0 mass% and 0.50 mass% or less>

The flux-cored wire in the present embodiment preferably further contains, as an optional component, at least one selected from Nb, Zr, and V in a total amount of 0.50 mass%

or less. This is because oxides formed of these elements are stable, and in the case where these elements are contained in the wire, a high deoxidizing effect is easily obtained. The total amount of these elements is preferably 0.50 mass% or less, and more preferably 0.40 mass% or less.

5 [0040]

<B: more than 0 mass% and 0.0080 mass% or less>

The flux-cored wire in the present embodiment preferably further contains, as an optional component, B in an amount of more than 0 mass% and 0.0080 mass% or less. B can improve the hardenability of the weld metal during quenching.

10

In the case where B is contained in the wire, B is added to the weld metal through the wire and the strength of the weld metal can be improved by the quenching effect even if the content of B is very small. Therefore, in the case where B is contained in the steel sheath and the flux, the content of B is preferably more than 0 mass%, and more preferably 0.0040 mass% or more.

15

On the other hand, in the case where the content of B is 0.0080 mass% or less, decrease in toughness of the weld metal can be prevented, and the hot cracking susceptibility can be lowered. Therefore, in the case where B is contained in the steel sheath and the flux, the content of B is preferably 0.0080 mass% or less, and more preferably 0.0075 mass% or less.

20 [0041]

<Bi: 0.010 mass% or more and 0.100 mass% or less>

The flux-cored wire in the present embodiment preferably further contains, as an optional component, Bi in an amount of 0.010 mass% or more and 0.100 mass% or less. Bi is an element essential for improving the peelability of welding slag occurred during welding.

25

In the case where the content of Bi is 0.010 mass% or more, the effect of improving the peelability of the welding slag is obtained. Therefore, in the case where Bi is contained in the steel sheath and the flux, the content of Bi is preferably 0.010 mass% or more, and more preferably 0.015 mass% or more.

On the other hand, in the case where the content of Bi is 0.100 mass% or less, the hot cracking susceptibility of the weld metal can be lowered. Therefore, in the case where Bi is contained in the steel sheath and the flux, the content of Bi is preferably 0.100 mass% or less, and more preferably 0.080 mass% or less.

30

Bi is mainly added to the flux as an oxide such as Bi_2O_3 , but may be added to the

wire in the form of a Fe-Bi alloy, a Bi metal, or the like. In the present embodiment, the content of each of the Bi oxide, the Bi metal, and the Bi alloy is specified as a value in terms of Bi, and the Bi converted value is simply referred to as the content of Bi.

[0042]

5 <Fe: 85 mass% or more>

Fe is a main component of the flux-cored wire. From the deposition amount and the relationship with the composition of other components, the content of Fe is preferably 85 mass% or more, more preferably 87 mass% or more, and preferably 95 mass% or less, and more preferably 93 mass% or less, relative to the total mass of the wire.

10 [0043]

<Remainder>

The remainder of the flux-cored wire in the present embodiment contains inevitable impurities. The flux-cored wire in the present embodiment may further contain Al, Ta, W, Sn, F, K, Mg, a rare earth element (REM), and Ca, if necessary, in addition to the above-

15 described components in the wire. Although Sn does not inhibit the hydrochloric acid dew point corrosion resistance of the weld metal even in a case where Sn is added to or contained in the wire as an inevitable impurity, the content of Sn in the steel sheath and the flux is preferably restricted to 0.05 mass% or less because the toughness of the welded joint is significantly reduced in the case where the content of Sn is more than 0.05 mass%.

20

In the flux-cored wire in the present embodiment, the total content of the elements whose contents are defined as described above, Fe, and the elements of the remainder is preferably 94 mass% or more, more preferably 95 mass% or more, and still more preferably 96 mass% or more, relative to the total mass of the wire. Examples of the other components include oxygen of the oxide, nitrogen and the like. For example, it is practical that the

25 content of oxygen is within the range of 1 mass% to 5 mass%.

[0044]

<Others: filling ratio of flux>

The filling ratio of the flux ($= \text{mass of flux} / \text{total mass of wire} \times 100$) of the flux-cored wire in the present embodiment is not particularly limited.

30

Here, in a case where the filling ratio of the flux is less than 10 mass%, the arc stability may deteriorate, the spatter generation may increase, and the weldability may become poor. Therefore, the filling ratio of the flux is preferably 10 mass% or more, and more preferably 12 mass% or more.

On the other hand, in a case where the filling ratio of the flux is more than 30 mass%, the productivity decreases, e.g. disconnection of the wire occurs or powder spills during filling of the flux. Therefore, the filling ratio of the flux is preferably 30 mass% or less, and more preferably 25 mass% or less.

5 [0045]

[Method for producing flux-coated wire]

A method for producing the flux-cored wire in the present embodiment is not particularly limited, and the flux-cored wire can be produced by, for example, the following method.

10 First, a steel strip constituting a steel sheath is prepared, and the steel strip is formed into a U-shaped open tube by a forming roller while being fed in a longitudinal direction. Next, the steel sheath is filled with a flux obtained by blending various raw materials to reach a predetermined component composition, and then, the steel sheath filled with the flux is processed to have a circular cross section. Thereafter, the wire is drawn by cold processing,
15 thereby obtaining a flux-cored wire having a wire diameter of, for example, 1.2 mm to 2.4 mm.

Annealing may be performed in the middle of the cold processing. In addition, it is possible to employ any structure of a seamless wire formed by welding joints of a steel sheath formed in a production process and a wire in which a gap is left without welding the
20 joints.

Examples

[0046]

Hereinafter, the present invention is described in more detail with reference to
25 Invention Examples and Comparative Examples, but the present invention is not limited thereto.

[0047]

A steel sheath was filled with a flux obtained by appropriately blending raw materials, and a flux-cored wire having a wire diameter of 1.2 mm was produced such that a
30 ratio of the flux to the total mass of the wire was 15 mass%. The contents (mass%) of the chemical components in the flux-cored wires in Invention Examples and Comparative Examples are shown in Tables 1 and 2 below.

The content of each chemical component shown in Table 1 or 2 is the content

(mass%) relative to the total mass of the wire. The remainder was inevitable impurities. Further, “57[Mo] + 221[Co]” shown in Table 1 indicates a value calculated by the left side of the relationship (1).

In Tables 1 and 2, the notation “-” in each component composition means that the content is less than 0.005 mass%.

[0048]

Next, FIG. 1A is a schematic diagram showing a location of a test piece of a welded joint subjected to a hydrochloric acid corrosion resistance test. FIG. 1B is a schematic diagram showing a location of a reference test piece subjected to a hydrochloric acid corrosion resistance test. As shown in FIG. 1A, two steel sheets 1 having a thickness of 6 mm were used, and grooves were formed such that a groove angle was 60°. Then, the two steel sheets were butted with each other with a root gap of 5 mm, and a backing material 4 was disposed on a back surface opposite to the surface to be welded. The steel sheet 1 is commercially available as sulfuric acid-resistant and hydrochloric acid-dew-point steel (so-called market steel sheet), and the main chemical components other than Fe and the contents thereof are shown in Table 3 below.

Thereafter, two steel sheets 1 were subjected to butt welding under the welding conditions shown in Table 4 below, and each of a front surface and a back surface of the joined steel sheets 1 were polished by 1 mm. Further, the front surface and back surface of the obtained weld metal 3 were also appropriately polished, and then a side surface was cut, thereby producing a test piece 2 of the welded joint having a width of 25 mm, a length of 60 mm, and a thickness of 4 mm.

[0049]

Further, as shown in FIG. 1B, each of a front surface and a back surface of the steel sheet 11 having a thickness of 6 mm were polished by 1 mm. Further, a side surface was cut, thereby preparing a reference test piece 12 having a width of 25 mm, a length of 60 mm, and a thickness of 4 mm. The steel sheet 11 used for the reference test piece 12 is also as shown in Table 3 below, similarly to the steel sheet 1.

[0050]

Thereafter, a corrosion test in which the test piece 2 of the welded joint and the reference test piece 12 were immersed in a test solution was performed under the corrosion test conditions shown in Table 5 below, and the corrosion rate ($\text{mg}/\text{cm}^2/\text{hr}$) was calculated from the weight difference before and after the corrosion test and the surface area before

corrosion. In this case, since the corrosion rate generally varies for each test, the same corrosion test was performed on the reference test piece 12 for each corrosion test, and a ratio of a corrosion rate of the test piece 2 of the welded joint relative to a corrosion rate of the reference test piece 12 was determined as the corrosion rate ratio. That is, the corrosion rate ratio of 1.00 indicates that the corrosion rate of the weld metal is equal to the corrosion rate of the reference test piece 12 (that is, the market steel sheet) that is not welded.

[0051]

The corrosion rate ratios and evaluation results obtained in the respective tests are shown in Table 6 below. The lower the corrosion rate ratio is, the less the corrosion has progressed. As an evaluation criteria, a corrosion rate ratio of less than 0.85 was defined as Evaluation A (excellent), a corrosion rate ratio of 0.85 or more and less than 0.95 was defined as Evaluation B (good), a corrosion rate ratio of 0.95 or more and less than 1.00 was defined as Evaluation C (slightly good), and a corrosion rate ratio of 1.00 or more was defined as Evaluation D (poor).

[0052]

Table 1

Wire No.	Chemical components (mass%) in flux-cored wire												
	Fe	C	Si	Mn	P	S	Cu	Ni	Mo	Co	57[Mo] + 221[Co]	Sb	Cr
1	89.70	0.03	0.81	2.10	0.009	0.004	0.39	0.32	-	-	0	0.11	-
2	89.63	0.03	0.79	2.07	0.009	0.004	0.38	0.54	-	-	0	0.11	-
3	90.00	0.05	1.15	2.61	0.016	0.006	0.40	0.27	0.05	-	3	0.10	-
4	89.72	0.03	0.79	2.04	0.009	0.004	0.38	0.31	0.25	0.007	16	0.11	-
5	89.82	0.03	0.79	2.04	0.009	0.004	0.38	0.31	0.15	0.007	10	0.11	
6	90.11	0.03	0.79	1.65	0.009	0.004	0.38	0.31	0.25	0.007	16	0.11	-
7	89.69	0.06	0.79	2.04	0.009	0.004	0.38	0.31	0.25	0.007	16	0.11	-
8	89.38	0.04	0.79	2.05	0.010	0.005	0.38	0.31	0.25	-	14	0.11	-
9	89.71	0.03	0.79	2.04	0.009	0.004	0.38	0.31	0.25	0.014	17	0.11	-
10	89.15	0.03	0.93	2.11	0.009	0.004	0.39	0.32	-	-	0	-	0.50
11	89.81	0.03	0.79	2.04	0.009	0.004	0.38	0.31	0.15	0.040	18	0.11	-
12	89.81	0.03	0.79	2.04	0.009	0.004	0.38	0.31	0.15	0.094	29	0.11	-
13	89.81	0.03	0.79	2.04	0.009	0.004	0.38	0.31	0.25	0.040	23	0.11	-

[0053]

Table 2

Wire No.	Chemical components (mass%) in flux-cored wire												
	Ti	Na	Nb	Zr	V	[Nb] + [Zr] + [V]	B	Bi	Al	F	K	Mg	Sn
1	2.9	0.034	0.01	0.30	0.01	0.32	0.0069	-	0.16	0.07	0.09	0.26	0.01
2	2.9	0.033	0.01	0.30	0.01	0.32	0.0068	-	0.16	0.07	0.08	0.25	0.01
3	4.1	-	-	-	0.01	0.01	0.0010	-	0.15	-	-	-	-
4	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
5	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
6	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
7	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
8	2.8	0.033	0.01	0.59	0.01	0.61	0.0067	-	0.16	0.07	0.08	0.25	0.01
9	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
10	2.9	0.034	0.01	0.30	0.01	0.32	0.0069	-	0.16	0.07	0.09	0.26	0.01
11	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
12	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01
13	2.8	0.033	0.01	0.29	0.01	0.31	0.0067	-	0.16	0.07	0.08	0.25	0.01

[0054]

Table 3

Chemical components (mass%) in market steel sheet								
C	Si	Mn	P	S	Cu	Cr	Ti	Sb
0.03	0.81	2.10	0.009	0.004	0.39	0.03	0.000	0.11

[0055]

5 Table 4

Welding conditions	
Welding material to be tested (diameter)	Flux-cored wire including chemical components described in Tables 1 and 2 (1.2 mm)
Steel sheet to be tested, shape	Market steel sheet including chemical composition described in Table 3, Thickness: 6 mm, Groove shape: V, Groove angle: 60°, Root gap: 5 mm
Welding position	Flat
Pass sequence	Two passes and two layers
Preheating and interpass temperature	No preheating, interpass temperature: 150°C
Polarity of power source	DCEP
Shielding gas, flow rate	100% CO ₂ , 25 L/min
Welding current	260 A

[0056]

Table 5

Corrosion test conditions	
Processing before and after test	Before test: Acetone degreasing After test: Washing and drying
Test temperature	80°C (depending on constant temperature water tank management)
Test solution and concentration	20% HCl
Amount of test liquid	500 ml per test piece
Test time	6 hours
Atmosphere	In the air

10 [0057]

Table 6

Test No.	Wire No.	Invention Example / Comparative Example	Corrosion rate ratio	Evaluation result
1	1	Comparative Example	1.01	D
2	2	Comparative Example	1.08	D
3	3	Comparative Example	1.08	D
4	4	Invention Example	0.96	C
5	5	Comparative Example	1.02	D
6	6	Invention Example	0.95	C
7	7	Invention Example	0.97	C
8	8	Comparative Example	1.00	D
9	9	Invention Example	0.97	C
10	10	Comparative Example	1.15	D
11	11	Invention Example	0.99	C
12	12	Invention Example	0.85	B
13	13	Invention Example	0.80	A

[0058]

As shown in Table 6 above, in Test Nos. 1 and 2 that were Comparative Examples, the content of Mo and the content of Co were less than the lower limit of the numerical range of the present invention, and “ $57 \times [\text{Mo}] + 221 \times [\text{Co}] \geq 15$ ” (that is, relationship (1)) was not satisfied. Therefore, a weld metal having excellent hydrochloric acid corrosion resistance could not be obtained, and the evaluation results of the corrosion tests were D (poor).

In Test Nos. 3 and 8 that were Comparative Examples, the content of Co was less than the lower limit of the numerical range of the present invention and the relationship (1) was not satisfied. Therefore, a weld metal having excellent hydrochloric acid corrosion resistance could not be obtained, and the evaluation results of the corrosion tests were D (poor).

[0059]

In Test No. 5 that was a Comparative Example, the content of Mo and the content of Co were within the numerical ranges of the present invention, but the relationship (1) was not satisfied. Therefore, a weld metal having excellent hydrochloric acid corrosion resistance could not be obtained, and the evaluation result of the corrosion test was D (poor).

In Test No. 10 that was a Comparative Example, the content of Mo and the content of Co were less than the lower limit of the numerical range of the present invention, the relationship (1) was not satisfied, the content of Sb was less than the lower limit of the numerical range of the present invention, and the content of Cr is more than the upper limit of

the numerical range of the present invention. Therefore, the evaluation result of the corrosion test was extremely bad (evaluation result D, corrosion rate ratio: 1.15).

[0060]

In contrast, Test Nos. 4, 6, 7, 9, and 11 to 13, which were Invention Examples, all satisfied the numerical ranges specified in the present invention. Therefore, weld metals having excellent hydrochloric acid corrosion resistance could be obtained (evaluation results A to C).

In Test Nos. 12 and 13, the content of Mo and the content of Co were relatively high, and the value calculated from the left side of the relationship (1) was a large value being 20 or more. Therefore, a weld metal having remarkably excellent hydrochloric acid corrosion resistance could be obtained (evaluation results A and B).

[0061]

As described above in detail, in the present invention, it is possible to obtain a flux-cored wire for gas shielded arc welding, by which a weld metal having excellent hydrochloric acid corrosion resistance can be obtained.

[0062]

Although various embodiments are described above with reference to the drawings, it is needless to say that the present invention is not limited to these embodiments. It will be apparent to those skilled in the art 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 spirit of the present invention.

[0063]

The present application is based on Japanese Patent Application No. 2018-219177 filed on November 22, 2018, and the contents thereof are incorporated herein by reference.

CLAIMS

1. A flux-cored wire for gas shielded arc welding, which has a steel sheath filled with a flux, the flux-cored wire comprising,

relative to a total mass of the wire:

C: 0.02 mass% or more and 0.10 mass% or less;

Si: 0.05 mass% or more and 1.00 mass% or less;

Mn: 1.5 mass% or more and 3.0 mass% or less;

S: 0.003 mass% or more and 0.030 mass% or less;

Cu: 0.05 mass% or more and 0.50 mass% or less;

Ni: 0.05 mass% or more and 0.50 mass% or less;

Mo: 0.05 mass% or more and 0.35 mass% or less;

Co: 0.005 mass% or more and 0.300 mass% or less; and

Sb: 0.01 mass% or more and 0.20 mass% or less,

wherein a content of P is restricted to 0.030 mass% or less,

a content of Cr is restricted to 0.05 mass% or less, and

the following relationship (1) is satisfied:

$$57 \times [\text{Mo}] + 221 \times [\text{Co}] \geq 15 \quad (1)$$

wherein [Mo] represents the content (mass%) of Mo in the steel sheath and flux

relative to the total mass of the wire, and [Co] represents the content (mass%) of Co in the steel sheath and flux relative to the total mass of the wire.

2. The flux-cored wire according to claim 1, further comprising Ti in an amount of 2.0 mass% or more and 4.5 mass% or less relative to the total mass of the wire.

3. The flux-cored wire according to claim 1 or 2, further comprising a slag forming agent, wherein a total content of Na, K, Li, Mg, and F in the slag forming agent is 0.010 mass% or more and 1.500 mass% or less relative to the total mass of the wire.

4. The flux-cored wire according to claim 1 or 2, further comprising at least one kind selected from Nb, Zr, and V, wherein a total content of Nb, Zr, and V is more than 0 mass% and 0.50 mass% or less relative to the total mass of the wire.

5. The flux-cored wire according to claim 1 or 2, further comprising B in an amount of more than 0 mass% and 0.0080 mass% or less relative to the total mass of the wire.