

DESCRIPTION

TITLE OF INVENTION

COATED ARC WELDING ROD AND COATED ARC WELDING METHOD

5

TECHNICAL FIELD

[0001]

The present invention relates to a covered electrode and a shielded metal arc welding method, and more particularly to a covered electrode by which droplets can be smoothly transferred by preventing deflection of an arc and maintaining good arc stability, and excellent weldability can be obtained, and a shielded metal arc welding method for performing arc welding using the covered electrode.

10

BACKGROUND ART

15 [0002]

Shielded metal arc welding is a welding method for joining an object to a base metal by using a covered electrode (also simply referred to as an “electrode”, “welding rod” or the like) in which a flux or a protective material referred to as a coating agent is provided on a metal rod (core wire), generating an arc between the covered electrode and the base metal, and melting the electrode and base metal with arc heat. The shielded metal arc welding is the simplest welding method that does not require shielding gas. The shielded metal arc welding can be performed even in outdoors with strong wind, and is widely used in various manufacturing factories, buildings, ships, vehicles, and the like.

20

[0003]

The coating agent constituting the covered electrode contains raw materials having functions such as a gas generating agent, a slag forming agent, a deoxidizing agent, an alloy additive, an arc stabilizer, and a fixing agent. In addition, the covered electrode is classified depending on the kind of coating agents, and there are various kinds of covered electrodes such as an illuminite-based covered electrode, a high titanium oxide-based covered electrode, a lime titania-based covered electrode, an iron powder titanium oxide-based covered electrode, a high cellulose-based covered electrode, a low hydrogen-based covered electrode, and an iron powder low hydrogen-based covered electrode.

25

30

[0004]

Among the various kinds of covered electrodes described above, a covered electrode, in which an oxygen content in a core wire is limited and contents of metal carbonates, metal fluorides, and water in a coating agent are appropriately adjusted, has been proposed as a low hydrogen-based covered electrode as described in Patent Literature 1.

5 Patent Literature 1 discloses that components in a core wire and coating agent of the covered electrode are appropriately adjusted to ensure good weldability without impairing physical properties of a weld metal.

CITATION LIST

10 PATENT LITERATURE

[0005]

Patent Literature 1: JP-A-S57-85696

SUMMARY OF INVENTION

15 TECHNICAL PROBLEM

[0006]

However, welding using a covered electrode is performed in various welding positions such as a push angle and a drag angle. Thus, when the electrode is tilted, a part of the coating agent, the part being close to the base metal, is easy to be melted (this is referred to as one-sided melting), and the arc is deflected, which deteriorates the welding work. As to the covered electrode described in Patent Literature 1 described above, nothing about the one-sided melting and the deflection of an arc is described, and the covered electrode is specially applied to a low hydrogen-based covered electrode. Thus, the other covered electrodes described in Patent Literature 1 could not improve weldability evaluated in the droplet transferability and the arc stability for the other kinds of covered electrodes.

25

[0007]

An object of the present invention is to provide a covered electrode by which excellent weldability can be obtained since one-sided melting and deflection of an arc can be prevented, droplets can be smoothly transferred, and good arc stability is good.

30

SOLUTION TO PROBLEM

[0008]

The covered electrode in the present invention constitutes of the following

configuration (1).

(1) A covered electrode comprising:

a core wire; and a coating agent that covers the core wire,

wherein the coating agent contains at least one of a metal carbonate and a metal

5 fluoride,

a total of a content (CO₂ conversion value) of a metal carbonate having a grain diameter of 75 μm or more ($C_{CO_2, 75 \mu m}$) and a content (F conversion value) of a metal fluoride having a grain diameter of 75 μm or more ($C_{F, 75 \mu m}$) relative to a total mass of the coating agent ($C_{coat, total}$) is 6.0 mass% or more (where a case of at least one of the $C_{CO_2, 75 \mu m}$ and the

10 $C_{F, 75 \mu m}$ being 0 mass% is included), and

on an electrode distal end side after use of the covered electrode, a ratio of D_2 to D_1 (D_2/D_1) satisfies 0.40 or less (including the case where the ratio is 0),

wherein D_1 is a distance between a distal end portion of the core wire and the most distal end portion of the coating agent remaining around the core wire in a longitudinal

15 direction of the electrode, and

D_2 is a distance between the most distal end portion of the coating agent remaining around the core wire and the rearmost portion of the coating agent remaining around the core wire in the longitudinal direction of the electrode.

[0009]

20 In addition, preferable embodiments of the covered electrode in the present invention constitute of the following configuration (2) or (3).

(2) The covered electrode according to the above (1), wherein the D_1 satisfies 2.2 mm or less.

(3) The covered electrode according to the above (1) or (2), wherein a ratio of the D_1 to a diameter d of the core wire in the covered electrode (D_1/d) satisfies 1.3 or less.

[0010]

In addition, the covered electrode in the present invention constitutes of the following configuration (4).

(4) A covered electrode comprising:

30 a core wire; and a coating agent that covers the core wire,

wherein the coating agent contains at least one of a metal carbonate and a metal fluoride, and

a total of a content (CO₂ conversion value) of a metal carbonate having a grain

diameter of 75 μm or more ($C_{\text{CO}_2, 75 \mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of 75 μm or more ($C_{\text{F}, 75 \mu\text{m}}$) relative to a total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more (where a case of at least one of the $C_{\text{CO}_2, 75 \mu\text{m}}$ and the $C_{\text{F}, 75 \mu\text{m}}$ being 0 mass% is included).

5 [0011]

In addition, preferable embodiments of the covered electrode in the present invention constitute of the following configurations (5) to (10).

(5) The covered electrode according to any one of the above (1) to (4),
 wherein in a cross section perpendicular to a longitudinal direction of the electrode,
 10 a ratio of S_2 to S_1 (S_2/S_1) satisfies 0.06 or more and 0.15 or less,
 wherein S_1 is a cross-sectional area of the entire coating agent, and
 S_2 is a total area of at least one of the metal carbonate and the metal fluoride, each
 having an equivalent circle diameter of 30 μm or more.

(6) The covered electrode according to any one of the above (1) to (5),
 15 wherein the coating agent contains at least one selected from CaCO_3 , BaCO_3 ,
 SrCO_3 , MgCO_3 and MnCO_3 as the metal carbonate, and
 a total content (CO_2 conversion value) of the metal carbonate in the coating agent
 ($C_{\text{CO}_2, \text{total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) satisfies 6.0 mass% or
 more and 26.0 mass% or less.

(7) The covered electrode according to any one of the above (1) to (6),
 20 wherein the coating agent contains at least one selected from CaF_2 , BaF_2 , SrF_2 and
 MgF_2 as the metal fluoride, and
 a total content (F conversion value) of the metal fluoride in the coating agent ($C_{\text{F, total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 15.0 mass% or less (including
 25 0 mass%).

(8) The covered electrode according to any one of the above (1) to (7),
 wherein the coating agent contains the metal carbonate and the metal fluoride, and
 a ratio of a total content (F conversion value) of the metal fluoride in the coating
 agent ($C_{\text{F, total}}$) relative to a total of a total content (CO_2 conversion value) of the metal
 30 carbonate in the coating agent ($C_{\text{CO}_2, \text{total}}$) and the total content (F conversion value) of the
 metal fluoride ($C_{\text{F, total}}$) in the coating agent $\{C_{\text{F, total}}/(C_{\text{CO}_2, \text{total}} + C_{\text{F, total}})\}$ satisfies 0.10 or more
 and 0.30 or less.

(9) The covered electrode according to any one of the above (1) to (8),

wherein the coating agent further contains at least one of Si and a Si compound, and a total content (Si conversion value) of the Si and the Si compound ($C_{\text{Si, total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more and 9.0 mass% or less.

(10) The covered electrode according to any one of the above (1) to (9), wherein the covered electrode is used in arc welding based on a welding position in which the covered electrode is perpendicular to a base metal or has a drag angle of more than 0° and 30° or less.
[0012]

In addition, the shielded metal arc welding method in the present invention constitutes of the following configuration (11).

(11) A shielded metal arc welding method using a covered electrode including a core wire and a coating agent that covers the core wire,

wherein the coating agent contains at least one of a metal carbonate and a metal fluoride, and

a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{CO}_2, 75\ \mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{F}, 75\ \mu\text{m}}$) relative to a total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more (where a case of at least one of the $C_{\text{CO}_2, 75\ \mu\text{m}}$ and the $C_{\text{F}, 75\ \mu\text{m}}$ being 0 mass% is included).
[0013]

In addition, preferable embodiments of the shielded metal arc welding method in the present invention constitute of the following configurations (12) to (15)

(12) The shielded metal arc welding method according to the above (11), wherein, on an electrode distal end side after use of the covered electrode, a ratio of D_2 to D_1 (D_2/D_1) satisfies 0.40 or less (including the case where the ratio is 0),

wherein D_1 is a distance between a distal end portion of the core wire and the most distal end portion of the coating agent remaining around the core wire in a longitudinal direction of the electrode, and

D_2 is a distance between the most distal end portion of the coating agent remaining around the core wire and the rearmost portion of the coating agent remaining around the core wire in the longitudinal direction of the electrode.

(13) The shielded metal arc welding method according to the above (12), wherein arc welding is performed such that the D_1 satisfies 2.2 mm or less.

(14) The shielded metal arc welding method according to the above (12) or (13),

wherein arc welding is performed such that a ratio of the D_1 to a diameter d of the core wire in the covered electrode (D_1/d) satisfies 1.3 or less.

(15) The shielded metal arc welding method according to any one of the above (11) to (14), wherein arc welding is performed in a welding position in which the covered electrode is perpendicular to a base metal or has a drag angle of more than 0° and 30° or less.

ADVANTAGEOUS EFFECTS OF INVENTION

[0014]

In the present invention, a predetermined amount of grains having a suitable size is contained by controlling a grain size of at least one kind of grains selected from metal carbonates and metal fluorides contained in a coating agent, and therefore, the coating agent is uniformly melted, whereby a protective sheath is uniformly formed during welding, one-sided melting is prevented, and deflection of an arc is prevented. As a result, the arc stability is further improved. Accordingly, it is possible to provide a covered electrode and a shielded metal arc welding method, by which excellent weldability can be obtained even for all kinds of covered electrodes.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

[FIG. 1A] FIG. 1A is a cross-sectional view illustrating a state of a covered electrode in a case where deflection of an arc is prevented during welding.

[FIG. 1B] FIG. 1B is a cross-sectional view illustrating a state of a covered electrode in a case where deflection of an arc is remarkably generated during welding.

DESCRIPTION OF EMBODIMENTS

[0016]

Embodiments of the present invention are described in detail below. 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 focused on the grain size (size of grains) of a metal carbonate or metal fluoride contained in a coating agent, and have made intensive studies to obtain a covered electrode, by which smooth droplet transfer and good arc stability can be

achieved. As a result, the present inventors have found that it is effective that grains having a large size among the grains of the metal carbonate or the metal fluoride are adjusted to be contained in a predetermined amount.

[0018]

5 First, an influence (that is, action and effect) of the grain size (that is, the coarse grain diameter) of the metal carbonate or the metal fluoride on the droplet transfer is described in detail below.

[0019]

10 The present inventors have found that the grain size of the metal carbonate or the metal fluoride also affects a shape of a protective sheath formed during arc welding, and thus, the directivity of an arc is maintained, that is, the deflection of the arc is prevented, so that good arc stability can be obtained.

That is, when a metal carbonate or metal fluoride having a large grain size is contained in the coating agent, the specific surface area becomes small and the coating agent is hardly melted, and thus, the coating agent is uniformly melted during arc welding, thereby uniformly forming a protective sheath during welding (for details, see the contents described later). Therefore, the arc directivity is maintained, so that the arc stability is further improved.

[0020]

20 The metal carbonate or the metal fluoride is a component that may be contained as a gas generating agent in the coating agent, and plays a role in preventing oxygen, nitrogen, or the like in the atmosphere from entering into a weld metal by generating a shielding gas when a covered electrode is used as an electrode and an arc is generated between the covered electrode and the base metal.

25 When the grain size of the metal carbonate or metal fluoride contained in the coating agent is adjusted to be large, the metal carbonate or the metal fluoride having a large grain size is retained at one location until it is completely gasified at a distal end of the covered electrode (arc generation point on an electrode side). Due to this retention at one location, a gas is intensively generated in one direction (a direction of a melted core wire), and the formation of the constriction of droplets is promoted by the effect of the volume expansion of the gas. For this reason, a shearing force for releasing the droplets, such as an electromagnetic pinch force or a surface tension, efficiently acts, and the droplets can be separated in a small-grain state. In addition, the droplets are released while stably

30

maintaining a separation period, so that the arc stability is improved, and excellent weldability can be obtained.

[0021]

On the other hand, in a case where the grain size of the metal carbonate or the metal fluoride is small, the amount of gas generated is small. Thus, a small volume of gas is generated, and the direction of gas generated is not fixed to one direction, and thus, the force of promoting the release of the droplets is small as compared with the case where the grain size of the metal carbonate or the metal fluoride is large.

[0022]

Hereinafter, regarding the covered electrode in the embodiment of the present invention, the grain size, an area ratio of a cross section of the electrode in a longitudinal direction, a reason for addition of other components, a reason for numerical limitation, and the like, in the gas generating agent contained in the coating agent, are described in detail.

[0023]

The covered electrode in the present embodiment includes:
a core wire; and a coating agent that covers the core wire, in which
the coating agent contains at least one of a metal carbonate and a metal fluoride,
a total of a content (CO_2 conversion value) of a metal carbonate having a grain
diameter of $75\ \mu\text{m}$ or more ($C_{\text{CO}_2, 75\ \mu\text{m}}$) and a content (F conversion value) of a metal fluoride
having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{F}, 75\ \mu\text{m}}$) relative to a total mass of the coating
agent ($C_{\text{coat, total}}$) is 6.0 mass% or more (where a case of at least one of the $C_{\text{CO}_2, 75\ \mu\text{m}}$ and the
 $C_{\text{F}, 75\ \mu\text{m}}$ being 0 mass% is included), and

on an electrode distal end side after use of the covered electrode, a ratio of D_2 to D_1
(D_2/D_1) satisfies 0.40 or less (including the case of the ratio being 0),

in which D_1 is a distance between a distal end portion of the core wire and the most
distal end portion of the coating agent remaining around the core wire in a longitudinal
direction of the electrode, and

D_2 is a distance between the most distal end portion of the coating agent remaining
around the core wire and the rearmost portion of the coating agent remaining around the core
wire in the longitudinal direction of the electrode.

[0024]

[Coating Agent]

First, details of the coating agent are described below.

[0025]

<A total value of content (CO_2 conversion value) of metal carbonate having grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{CO}_2, 75\ \mu\text{m}}$) and content (F conversion value) of metal fluoride having grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{F}, 75\ \mu\text{m}}$) relative to total mass of coating agent ($C_{\text{coat, total}}$): 6.0 mass% or more>

When the grain size of the metal carbonate or the metal fluoride contained in the coating agent is increased, the formation of the constriction of the droplets during arc welding can be promoted, and smooth droplet transfer can be achieved as described above. In addition, the coating agent is uniformly melted during the arc welding, so that a protective sheath is uniformly formed during welding. Therefore, the deflection of the arc is prevented and the arc directivity is maintained, so that the arc stability is further improved.

[0026]

When the coating agent contains a metal carbonate having a grain diameter of $75\ \mu\text{m}$ or more, or when the coating agent contains a metal fluoride having a grain diameter of $75\ \mu\text{m}$ or more, the above-described effects of smooth droplet transfer and good arc stability can be obtained. In this case, since a content of a metal carbonate having a grain diameter being equal to or larger than the predetermined value or a metal fluoride having a grain diameter being equal to or larger than the predetermined value can also affect the smooth droplet transfer and the arc stability, the content of the metal carbonate or the metal fluoride, each having a grain diameter being equal to or larger than the predetermined value, is also specified in the covered electrode according to the present embodiment.

[0027]

That is, when a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{CO}_2, 75\ \mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{F}, 75\ \mu\text{m}}$) relative to a total mass of a coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more, droplets can be smoothly transferred, the arc stability is improved, and an effect of improving weldability can be sufficiently obtained.

It should be noted that a case where at least one of $C_{\text{CO}_2, 75\ \mu\text{m}}$ and $C_{\text{F}, 75\ \mu\text{m}}$ is 0 mass% is included.

[0028]

When the total of the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{CO}_2, 75\ \mu\text{m}}$) and the content (F conversion value) of the metal fluoride having a grain diameter of $75\ \mu\text{m}$ or more ($C_{\text{F}, 75\ \mu\text{m}}$) is too large relative to the

total mass of the coating agent ($C_{\text{coat, total}}$), there is concern about an increase in spatter or an influence on the coatability of the coating agent during a production process. Therefore, the total of the $C_{\text{CO}_2, 75 \mu\text{m}}$ and the $C_{\text{F}, 75 \mu\text{m}}$ is preferably 15.0 mass% or less, and more preferably 12.0 mass% or less.

5 [0029]

In order to obtain the above-described effects of smooth droplet transfer and good arc stability more sufficiently, a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $106 \mu\text{m}$ or more ($C_{\text{CO}_2, 106 \mu\text{m}}$) and a content (F conversion value) of the metal fluoride having a grain diameter of $106 \mu\text{m}$ or more ($C_{\text{F}, 106 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 5.0 mass% or more. On the other hand, the above value is preferably 9.0 mass% or less because there is a concern about the increase in the spatter or the influence on the coatability of the coating agent during a production process described above.

[0030]

15 In order to obtain the above-described effects of smooth droplet transfer and good arc stability more sufficiently, a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $150 \mu\text{m}$ or more ($C_{\text{CO}_2, 150 \mu\text{m}}$) and a content (F conversion value) of the metal fluoride having a grain diameter of $150 \mu\text{m}$ or more ($C_{\text{F}, 150 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 2.5 mass% or more, and more preferably 3.0 mass% or more.

In addition, the above value is preferably 5.0 mass% or less, and more preferably 4.0 mass% or less because there is a concern about the increase in the spatter or the influence on the coatability of the coating agent during a production process described above.

[0031]

25 At least one of the above-described metal carbonate and the above-described metal fluoride should be contained in the coating agent, and both of them may be contained. The “grain diameter” described in the present embodiment is measured by the measurement method in accordance with JIS Z 8801-2006.

In addition, the grain size (grain diameter) of the metal carbonate and the metal fluoride contained in the coating agent is generally about $600 \mu\text{m}$ at the maximum.

[0032]

<Ratio of D_2 to D_1 (D_2/D_1): 0.40 or less (including the case where ratio is 0)>

As described above, the grain size of the metal carbonate and the metal fluoride also

affects the shape of the protective sheath after arc welding. That is, the protective sheath after the arc welding can be formed in a good shape by specifying the grain size and content of the metal carbonate and the metal fluoride. As a result, the arc directivity is further improved, and the arc stability is improved.

5 [0033]

Here, a state of a covered electrode in a case where arc welding is performed using two kinds of covered electrodes is described with reference to the drawings. In FIG. 1A and FIG. 1B, the same components are denoted by the same reference numerals, and a detailed description thereof is omitted.

10 [0034]

FIG. 1A is a cross-sectional view illustrating a state of a covered electrode in a case where deflection of an arc is prevented during welding. As illustrated in FIG. 1A, a covered electrode 1 includes a core wire 2 and a coating agent 3 that covers the core wire 2. The coating agent 3 contains at least one kind of compound selected from metal carbonates and metal fluorides. The components of the coating agent 3 are defined such that a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $75\text{ }\mu\text{m}$ or more ($C_{\text{CO}_2, 75\text{ }\mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of $75\text{ }\mu\text{m}$ or more ($C_{\text{F}, 75\text{ }\mu\text{m}}$) relative to a total mass of a coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more (where a case of at least one of the $C_{\text{CO}_2, 75\text{ }\mu\text{m}}$ and the $C_{\text{F}, 75\text{ }\mu\text{m}}$ being 0 mass% is included).

20

[0035]

When arc welding is performed on a base metal 5 by using the above-described covered electrode 1, the grain diameter and the total content of the specified compound (that is, at least one selected from the metal carbonates and the metal fluorides) contained in the coating agent 3 is limited as above, and therefore, a specific surface area of the above-described compound is reduced. As a result, melting or softening of the coating agent 3, strictly speaking, a protective sheath 6, which is a part protruding from a distal end portion 2a of the core wire 2 and is a part of the coating agent 3, hardly proceeds, and the protective sheath 6 is likely to remain during the arc welding.

25

30

Therefore, the one-sided melting of the coating agent 3 is prevented, and the coating agent 3 is uniformly melted over the entire circumferential direction of the covered electrode 1. As a result, during or after the welding, a space surrounded by an inner peripheral surface of the protective sheath 6 approaches a uniform conical shape in a cross-sectional view of the

covered electrode. As a result, a distance D between a distal end 3a of the protective sheath 6 and the distal end portion 2a of the core wire 2 in the longitudinal direction of the electrode is substantially the same at any position, and has a small variation. Therefore, fluctuation of an arc 4 during welding is prevented, the arc directivity is improved, and the arc stability is improved.

[0036]

As described later, in a case where both the metal carbonate and the metal fluoride are contained in the coating agent 3, and a ratio of a total content (F conversion value) of the metal fluoride ($C_{F, total}$) to a total of a total content (CO_2 conversion value) of the metal carbonate contained in the coating agent 3 ($C_{CO_2, total}$) and the total content (F conversion value) of the metal fluoride contained in the coating agent 3 ($C_{F, total}$) $\{C_{F, total}/(C_{CO_2, total} + C_{F, total})\}$ is appropriately adjusted, a softening point of the coating agent 3 can be increased. Therefore, a shape of the protective sheath 6 can be uniformly maintained up to an appropriate length, and the protective sheath 6 serves as a guide to increase the directivity of the arc. Accordingly, fluctuation of the droplets is further prevented, and good arc stability can be maintained, thereby improving weldability.

[0037]

On the other hand, FIG. 1B is a cross-sectional view illustrating a state of a covered electrode in a case where deflection of an arc is remarkably generated during welding. As illustrated in FIG. 1B, in a case where arc welding is performed by using a covered electrode 11 having a coating agent 13 in which the grain diameter and the content of the metal carbonate and the metal fluoride are not adjusted as described above, a difference between a distance between the distal end portion 2a of the core wire 2 and the most distal end portion 13a of the coating agent 13 (a protective sheath 16) remaining after the welding and a distance between the distal end portion 2a of the core wire 2 and the rearmost portion 13b of the coating agent 13 (a protective sheath 16) is observed. As a result, deflection of an arc 14 is remarkably generated during welding, and thus the arc stability decreases.

[0038]

In the present embodiment, variations in lengths of the coating agents 3, 13 remaining around the core wire 2 (or lengths of the protective sheaths 6, 16) after the use of the covered electrode are specified. Therefore, a method of digitizing the variation is described in detail with reference to FIG. 1B.

[0039]

As illustrated in FIG. 1B, on an electrode distal end side (a lower side of the covered electrode 11 in FIG. 1B) after the use of the covered electrode, a distance between the distal end portion 2a of the core wire 2 and the most distal end portion 13a of the coating agent 13 remaining around the core wire 2 in a longitudinal direction of the electrode (an upper-lower direction in FIG. 1B) is defined as D_1 , and a distance between the most distal end portion 13a of the coating agent 13 remaining around the core wire 2 and the rearmost portion 13b of the coating agent 13 remaining around the core wire 2 in the longitudinal direction of the electrode is defined as D_2 .

[0040]

When a ratio of D_2 to D_1 (D_2/D_1) satisfies 0.40 or less, it means that the protective sheath 16 with a small variation in length is formed in a good shape. When this requirement is satisfied, the directivity of the arc is obtained, and the arc stability is improved. The ratio of D_2 to D_1 (D_2/D_1) is preferably 0.30 or less, more preferably 0.25 or less, and most preferably 0.

[0041]

Here, a state after the use of the covered electrode (that is, a state after the end of the arc welding) refers to a state in which the coating agent remains after a continuous arc generation period of 5 seconds or longer has elapsed after the start of the arc welding.

In general, even after the covered electrode is used once, the covered electrode may be repeatedly used as long as the coating agent remains.

Note that, after the use of the covered electrode, slag may adhere to the distal end portion of the core wire 2, and in the present embodiment, the distal end portion 2a of the core wire 2 is specified in a state in which the slag is removed, and a shape of the distal end portion 2a is substantially planar.

In addition, the “most distal end portion” described in the present embodiment refers to the most protruding part of the distal ends of the coating agents 3, 13, and the “rearmost portion” refers to the least protruding part of the distal ends of the coating agents 3, 13.

[0042]

< D_1 : 2.2 mm or less>

It is preferable that, on the electrode distal end side after the use of the covered electrode, the coating agent 13 remains with a length equal to or larger than the certain length around the core wire 2, and the protective sheath 16 is formed. However, when the distance

D_1 between the distal end portion 2a of the core wire 2 and the most distal end portion 13a of the coating agent 13 remaining around the core wire 2 in the longitudinal direction of the electrode is more than 2.2 mm, a distance between the core wire and the base metal increases, and the arc length increases due to the excessive length of the protective sheath 16. When the arc length is excessively large, the arc length is likely to vary. Thus, non-continuous arc occurs and arc stability decreases. As a result, weldability may deteriorate due to deterioration of bead appearance and an increase in the spatter. Accordingly, the above D_1 is preferably 2.2 mm or less, and more preferably 1.7 mm or less. When the above D_1 is extremely small, the directivity of the arc is not obtained, and the arc stability deteriorates. Therefore, D_1 is preferably 1.0 mm or more, and more preferably 1.3 mm or more.

[0043]

<Ratio of D_1 to diameter d of core wire of covered electrode (D_1/d): 1.3 or less>

In general, the above D_1 is proportional to a diameter d (see d in FIG. 1B) of the core wire of the covered electrode. In order to maintain good arc stability, D_1/d is preferably 1.3 or less, more preferably 1.0 or less, and still more preferably 0.8 or less. When D_1 is extremely small relative to the above-described diameter d , the directivity of the arc is not obtained, and the arc stability deteriorates. Therefore, D_1/d is preferably 0.1 or more, and more preferably 0.3 or more.

In the present embodiment, the diameter d is not particularly limited, but is preferably 3.0 to 5.0 mm based on a range of the diameter d that is generally used.

[0044]

<Ratio of S_2 to S_1 (S_2/S_1): 0.06 or more and 0.15 or less>

In the present embodiment described above, smooth transfer of droplets and good arc stability are achieved by specifying the requirement that a predetermined amount of grains having a large grain size among at least one kind of grains selected from the metal carbonates and metal fluorides contained in the coating agent is contained.

On the other hand, in the present embodiment, the following is adopted as another specifying method for achieving these performances. Specifically, in the covered electrode, in a cross section perpendicular to the longitudinal direction of the electrode, when a cross-sectional area of the entire coating agent is defined as S_1 and a total area of at least one of the metal carbonate and the metal fluoride, each having an equivalent circle diameter of 30 μm or more is defined as S_2 , a ratio of S_2 to S_1 (S_2/S_1) satisfies 0.06 or more and 0.15 or less.

[0045]

When the ratio of S_2 to S_1 (S_2/S_1) is 0.06 or more, the effect of promoting the release of the droplets is exhibited more remarkably, and smoother droplet transfer can be achieved. Accordingly, the above S_2/S_1 is preferably 0.06 or more, and more preferably 0.07 or more.

On the other hand, when the above S_2/S_1 is 0.15 or less, it is easy to obtain a weld metal having desired performances. Accordingly, the above S_2/S_1 is 0.15 or less, and more preferably 0.10 or less.

[0046]

The above-described effects can be obtained even when only a metal fluoride having an equivalent circle diameter of 30 μm or more is contained within the above-described range in the coating agent, but it is more preferable that only a metal carbonate is contained within the above-described range. In addition, it is most preferable that both the metal carbonate and the metal fluoride are contained within the above range, respectively.

[0047]

Examples of a method of controlling the above S_2/S_1 as described above include a method of adjusting the grain diameter of the metal carbonate or metal fluoride as a raw material of the coating agent, a method of adjusting the content of the metal carbonate or metal fluoride, and a method of adjusting a coating pressure of the coating agent during the production of a covered electrode. The above S_2/S_1 can be controlled by using one of these methods alone or using these methods in combination. However, the above production method is merely an example, and the present invention is not limited to this example.

[0048]

In the present embodiment, the term “equivalent circle diameter” refers to a diameter of a circle having an area equal to a projected area of grains as defined in JIS Z 8827-1, and can be determined by image analysis software or the like based on a computer.

The grain size (equivalent circle diameter) of the metal carbonate and metal fluoride contained in the coating agent is generally about 600 μm at the maximum.

[0049]

Here, the above S_2/S_1 can be measured, for example, as follows. First, a cross section of an electrode is analyzed (at a magnification of 400 times) at an acceleration voltage of 15 kV and an irradiation current of 5×10^{-10} A by using a WD/ED combine Electron Probe Micro Analyzer (EPMA) JXA-8200 manufactured by JEOL Ltd.. Then, for the entire cross

section of the electrode, an area of at least one of the metal carbonate and the metal fluoride, each having an equivalent circle diameter of 30 μm or more, and the other areas are binarized using image analysis software JTrim. Accordingly, it is possible to calculate a ratio of a total area S_2 of at least one of the metal carbonate and the metal fluoride, each having an equivalent circle diameter of 30 μm or more, to a cross-sectional area S_1 of the entire coating agent (that is, S_2/S_1).

[0050]

<Total content (CO_2 conversion value) of metal carbonate in coating agent ($C_{\text{CO}_2, \text{total}}$) relative to total mass of coating agent ($C_{\text{coat, total}}$): 6.0 mass% or more and 26.0 mass% or less>

The metal carbonate, such as CaCO_3 and BaCO_3 , which is contained in the coating agent of the covered electrode, is a component having a function of protecting a molten pool from oxygen, nitrogen, and moisture in the atmosphere by generating CO_2 , which is a shielding gas, through thermal decomposition at a temperature approximate to an arc generation point. For example, CaCO_3 decomposes at about 825°C to generate CaO and CO_2 gas. When the content of the metal carbonate in the coating agent is too small, atmospheric entrainment occurs due to poor shielding, which causes deterioration in weldability, welding defects such as blow holes, and a decrease in an impact value of a weld metal.

In contrast, when the total content of the metal carbonate in the coating agent is excessive, the coating agent is less likely to melt during welding. That is, the distance of D_1 described above is increased, and thus, a distance between a melting interface of the core wire and the molten pool becomes excessively large, and the arc length deviates from an appropriate condition. Accordingly, non-continuous arc may occur or the arc stability may decrease, and the amount of spatter may increase.

As described above, by containing a metal carbonate having a size equal to or larger than the predetermined size, the droplet transfer period can be stabilized.

[0051]

When the total content (CO_2 conversion value) of the metal carbonate in the coating agent ($C_{\text{CO}_2, \text{total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more, these effects can be sufficiently obtained. Accordingly, the content of the above-described metal carbonate ($C_{\text{CO}_2, \text{total}}$), as the CO_2 conversion value, is preferably 6.0 mass% or more, and more preferably 10.0 mass% or more.

On the other hand, when the total content (CO_2 conversion value) of the metal carbonate in the coating agent ($C_{\text{CO}_2, \text{total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 26.0 mass% or less, the arc stability is further improved, and the amount of spatter generated is reduced. Accordingly, the content of the above-described metal carbonate ($C_{\text{CO}_2, \text{total}}$), as the CO_2 conversion value, is preferably 26.0 mass% or less, and more preferably 25.0 mass% or less.

For the same reason as described above, a total content (CO_2 conversion value) of a metal carbonate in a covered electrode relative to a total mass of the covered electrode $C_{\text{electrode, total}}$ is preferably 4.0 mass% or more and 10.0 mass% or less, more preferably 4.5 mass% or more and 9.0 mass% or less, and still more preferably 4.5 mass% or more and 7.5 mass% or less.

[0052]

The metal carbonate used as the coating agent in the present embodiment is preferably at least one selected from calcium carbonate (CaCO_3), barium carbonate (BaCO_3), strontium carbonate (SrCO_3), magnesium carbonate (MgCO_3) and manganese carbonate (MnCO_3). From the viewpoint of production cost, it is more preferable to use CaCO_3 and BaCO_3 , and it is most preferable to use CaCO_3 . Any one kind of the above-described various metal carbonates may be used, or a plurality of the various metal carbonates may be used in combination. In a case where a plurality of metal carbonates are used, a total content as the CO_2 conversion value is preferably within the range of 6.0 mass% or more and 26.0 mass% or less.

[0053]

In a case where CaCO_3 is contained as the metal carbonate in the coating agent, a content of CaCO_3 , as the CO_2 conversion value, in the coating agent relative to the total mass of the coating agent is preferably 6.0 mass% or more and 26.0 mass% or less, and more preferably 10.0 mass% or more and 25.0 mass% or less.

The content of CaCO_3 in the covered electrode relative to a total mass of the electrode is preferably 10.0 mass% or more and 20.0 mass% or less, more preferably 11.0 mass% or more and 19.0 mass% or less, and still more preferably 11.0 mass% or more and 17.0 mass% or less.

[0054]

When BaCO_3 is contained as the metal carbonate in the coating agent, a content of BaCO_3 , as the CO_2 conversion value, in the coating agent relative to the total mass of the

coating agent is preferably more than 0.0 mass% and 4.0 mass% or less, from the viewpoint of the weldability.

[0055]

<Total content (F conversion value) of metal fluoride in coating agent ($C_{F, \text{total}}$)

5 relative to total mass of coating agent $C_{\text{coat, total}}$: 15.0 mass% or less (including 0 mass%)>

The metal fluoride such as CaF_2 contained in the coating agent of the covered electrode is a component having an effect of improving a shape of a bead by lowering a melting point of slag and improving fluidity of the slag. In addition, the metal fluoride is a component having a function of preventing an increase in the amount of oxygen or hydrogen
10 in a weld metal and improving the arc stability by generating a large amount of reducing shielding gas (fluorine gas) through decomposition of the metal fluoride caused by the arc heat.

When the metal fluoride is added to the coating agent, decomposed fluorine reacts with hydrogen in a molten metal or a molten slag, and the partial pressure of hydrogen in the
15 molten metal may be lowered. Therefore, the amount of hydrogen in the weld metal may also be reduced. As described above, when the coating agent contains a metal fluoride having a size equal to or larger than a predetermined size, droplet transferability can be improved. However, when the content of the metal fluoride in the coating agent is excessive, the fluidity of the slag becomes excessive, and a defect such as slag inclusion may occur,
20 which may deteriorate the welding quality.

[0056]

The coating agent does not necessarily contain a metal fluoride, and the lower limit is not particularly set and may be 0.0 mass%. However, in order to sufficiently obtain these effects, it is preferable to add a metal fluoride, and the content of the metal fluoride is
25 preferably more than 0.0 mass%, and more preferably 3.0 mass% or more.

On the other hand, when the total content (F conversion value) of the metal fluoride in the coating agent ($C_{F, \text{total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 15.0 mass% or less, the better stability of an arc can be obtained, and the weldability is improved. Accordingly, the content of the metal fluoride ($C_{F, \text{total}}$) is preferably 15.0 mass% or less, and
30 more preferably 7.5 mass% or less.

For the same reason as described above, the total content (F conversion value) of the metal fluoride in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.5 mass% or more and 2.7 mass% or less, more preferably 0.7

mass% or more and 2.5 mass% or less, and still more preferably 0.9 mass% or more and 2.3 mass% or less.

[0057]

The metal fluoride used as the coating agent in the present embodiment is preferably at least one selected from calcium fluoride (CaF_2), barium fluoride (BaF_2), strontium fluoride (SrF_2), and magnesium fluoride (MgF_2). From the viewpoint of production cost, it is more preferable to use CaF_2 and BaF_2 , and it is most preferable to use CaF_2 . Any one kind of the above-described various metal fluoride may be used, or a plurality of the various metal fluorides may be used in combination. In a case where a plurality of metal fluorides are used, a total content as the F conversion value is preferably within a range of 15.0 mass% or less (including 0 mass%).

[0058]

In a case where CaF_2 is contained as a metal fluoride in the coating agent, the content of CaF_2 , as the F conversion value, in the coating agent relative to the total mass of the coating agent is preferably more than 0.0 mass% and 15.0 mass% or less, and more preferably 3.0 mass% or more and 7.5 mass% or less.

The content of CaF_2 in the covered electrode relative to the total mass of the electrode is preferably 1.0 mass% or more and 6.0 mass% or less, more preferably 1.5 mass% or more and 5.5 mass% or less, and still more preferably 1.8 mass% or more and 5.2 mass% or less.

[0059]

<Ratio of total content (F conversion value) of metal fluoride ($C_{\text{F, total}}$) to total of total content (CO_2 conversion value) of metal carbonate ($C_{\text{CO}_2, \text{ total}}$) and total content (F conversion value) of metal fluoride ($C_{\text{F, total}}$) in coating agent $\{C_{\text{F, total}}/(C_{\text{CO}_2, \text{ total}} + C_{\text{F, total}})\}$: 0.10 or more and 0.30 or less>

When the coating agent contains both the metal carbonate and the metal fluoride, the softening point of the flux can be increased by appropriately adjusting the mass ratio between the metal fluoride and the metal carbonate. As a result, the protective sheath can be stably formed with a desired length, and the arc directivity can be enhanced. Accordingly, fluctuation of the droplets is further reduced, good arc stability is obtained, and weldability is improved.

[0060]

When the above-described ratio $\{C_{\text{F, total}}/(C_{\text{CO}_2, \text{ total}} + C_{\text{F, total}})\}$ is 0.10 or more and

0.30 or less, the softening point of the flux can be appropriate, the protective sheath can remain with a sufficient length, and the weldability is further improved. Therefore, the above-described ratio is preferably 0.10 or more. The above-described ratio is preferably 0.30 or less, and more preferably 0.15 or less.

5 [0061]

<Total content (Si conversion value) $C_{\text{Si, total}}$ of Si and Si compounds in coating agent ($C_{\text{Si, total}}$) relative to total mass of coating agent $C_{\text{coat, total}}$: 6.0 mass% or more and 9.0 mass% or less>

10 Si and Si compounds are compounds that are in a form of SiO_2 in the coating agent and act as a catalyst to promote decomposition of the metal carbonate (CaCO_3). For example, CaCO_3 generates $\text{CaO} \cdot \text{SiO}_2$ and CO_2 gas in the presence of SiO_2 , and when CaCO_3 having a grain diameter of 75 μm or more is contained in a content that is equal to or larger than predetermined amount, the amount of CO_2 gas generated per unit time increases, and pinch force efficiently acts, thereby promoting the formation of the constriction of droplets.

15 When CaCO_3 is thermally decomposed, CaO generated thereby reacts with SiO_2 , and the thermal decomposition of undecomposed CaCO_3 is promoted by the reaction heat.

Si and the Si compound are in the form of SiO_2 in the coating agent and react with the metal fluoride to generate fluorine gas. For example, 2CaF_2 reacts with SiO_2 to generate 2CaO and SiF_4 gas. In this case, the SiF_4 gas generated by this reaction has a volume
20 smaller than that of the CO_2 gas generated by the metal carbonate using SiO_2 as a catalyst, so that the SiF_4 gas has a relatively small action of releasing the droplets.

[0062]

As described above, in the present embodiment, the total content of the metal fluoride having a grain diameter of 75 μm or more in the coating agent or the total area of the
25 metal fluoride having an equivalent circle diameter of 30 μm or more in a cross section perpendicular to the longitudinal direction of the electrode is specified, and this means that the metal fluoride having a large grain diameter is contained in the coating agent. Thus, the amount of gas generated is increased to promote the formation of the constriction of the droplets.

30 When the metal fluoride having a large grain diameter is contained in the coating agent, the following effects can be further obtained. That is, since the metal fluoride having a large grain diameter has a small specific surface area, the metal fluoride having a large grain diameter can inhibit a reaction between a metal fluoride (for example, CaF_2) and SiO_2 as

compared with a metal fluoride having a small grain diameter.

As described above, the amount of the SiF_4 gas generated by the reaction between the metal fluoride and SiO_2 is not significant as compared with the amount of the CO_2 gas generated by the above-described metal carbonate using SiO_2 as a catalyst. Therefore, for example, by inhibiting the reaction between CaF_2 and SiO_2 , it is possible to sufficiently ensure the amount of SiO_2 acting as a catalyst of the metal carbonate, and it is possible to promote the smoother release of the droplets.

[0063]

In a case where the coating agent further contains at least one of Si and Si compounds, and the total content (Si conversion value) of Si and Si compounds in the coating agent ($C_{\text{Si, total}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more, the generation of the CO_2 gas and the fluorine gas can be further promoted. Therefore, the above-described $C_{\text{Si, total}}$ is preferably 6.0 mass% or more.

On the other hand, when the above-described $C_{\text{Si, total}}$ is 9.0 mass% or less, it is easier to ensure predetermined mechanical performance and a stable bead shape in the weld metal. Therefore, the above-described $C_{\text{Si, total}}$ is preferably 9.0 mass% or less, and more preferably 8.0 mass% or less.

[0064]

Subsequently, the coating agent in the present embodiment may contain an alloy, an oxide, and the like in addition to the metal carbonate, the metal fluoride, Si and Si compounds. The other components are described below.

In the following description, the amount of each component in the coating agent is specified as the content relative to the total mass of the coating agent. The content of each component in the entire covered electrode is specified as the content relative to the total mass of the electrode.

[0065]

<Content of Fe in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 0.0 mass% or more (including 0 mass%) and 35.0 mass% or less>

Fe is a component to be added to the coating agent of the covered electrode for the purpose of improving the mechanical properties of the weld metal by deoxidizing action or addition of an alloy and improving the welding efficiency by increasing the metal welding amount, and Fe is contained in the form of Fe-Si, Fe-Mn, or the like in addition to being contained in the form of an iron powder in the coating agent. Fe in the coating agent may be

optionally added depending on the necessity of the above-described effect, and the lower limit is not particularly required to be specified, and may be 0.0 mass%. However, in the case of considering further improvement in mechanical performances, it is preferable to add Fe in an amount of 0.1 mass% or more in order to reduce the content of O in the weld metal. When the content of Fe in the coating agent is 35.0 mass% or less, it is possible to reduce the size of droplets to be transferred to the molten pool, and further improve the weldability.

Accordingly, in terms of the lower limit of the content of Fe in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$), the content of Fe is more preferably 0.1 mass% or more. In terms of the upper limit of the content of Fe in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$), the content of Fe relative to the total mass of the coating agent is preferably 35.0 mass% or less, more preferably 32.0 mass% or less, and still more preferably 30.0 mass% or less.

For the same reason as described above, the content of Fe in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 60.0 mass% or more and 85.0 mass% or less, more preferably 70.0 mass% or more and 85.0 mass% or less, and still more preferably 72.0 mass% or more and 85.0 mass% or less.

[0066]

<Content of Al in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 0.0 mass% or more (including 0 mass%) and 1.0 mass% or less>

Al (metal Al) is a component having an effect of improving the crack resistance of the weld metal and improving the corrosion resistance and the oxidation resistance, and may be added as necessary. The lower limit of Al is not particularly required to be specified, and may be 0.0 mass%. In a case where Al is added to the coating agent and the content of Al in the coating agent is 1.0 mass% or less, the weld metal can have sufficient ductility in addition to the above-described effects.

Accordingly, the content of Al in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 1.0 mass% or less, more preferably 0.8 mass% or less, and still more preferably 0.6 mass% or less.

For the same reason as described above, the content of Al in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.50 mass% or less (including 0 mass%), more preferably 0.30 mass% or less, and still more preferably 0.10 mass% or less.

[0067]

<Content of Ni in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$):
0.0 mass% or more (including 0 mass%) and 4.0 mass% or less>

Ni is a component having an effect of improving the fatigue strength of the weld portion, and may be added as necessary. The lower limit of Ni is not particularly required to be specified, and may be 0.0 mass%. In a case where Ni is added to the coating agent and the content of Ni in the coating agent is 4.0 mass% or less, hot cracks of the weld metal can be further prevented. Accordingly, the content of Ni in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 4.0 mass% or less, more preferably 3.0 mass% or less, and still more preferably 2.5 mass% or less.

For the same reason as described above, the content of Ni in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 1.00 mass% or less, more preferably 0.60 mass% or less, and still more preferably 0.30 mass% or less.

[0068]

<Content of Mn in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$):
1.5 mass% or more and 6.0 mass% or less>

Mn is a component having an effect of improving the strength of an alloy material, and may be added as necessary. The lower limit of Mn is not particularly required to be specified, and may be 0.0 mass%. When the content of Mn in the coating agent is within a range of 1.5 mass% or more and 6.0 mass% or less, hot cracks can be prevented while maintaining the strength of the weld metal. Accordingly, the content of Mn in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 1.5 mass% or more and 6.0 mass% or less, more preferably 1.7 mass% or more and 4.8 mass% or less, and still more preferably 1.8 mass% or more and 4.2 mass% or less.

For the same reason as described above, the content of Mn in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.8 mass% or more and 1.8 mass% or less, more preferably 0.8 mass% or more and 1.6 mass% or less, and still more preferably 0.8 mass% or more and 1.4 mass% or less.

[0069]

<Content of Si in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 1.0 mass% or more and 9.0 mass% or less>

Si (metal Si) is a deoxidizing agent and is a component having an effect of reducing the amount of oxygen in the weld metal and improving the strength of the weld metal. Si may be added as necessary. The lower limit of Si is not particularly required to be specified,

and may be 0.0 mass%. However, when the content of Si in the coating agent is within a range of 1.0 mass% or more and 9.0 mass% or less, the size of the droplets to be transferred to the molten pool can be further reduced, and the weldability is improved. Accordingly, the content of Si in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 1.0 mass% or more and 9.0 mass% or less, more preferably 2.4 mass% or more and 7.0 mass% or less, and still more preferably 2.8 mass% or more and 6.6 mass% or less.

For the same reason as described above, the content of Si in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.8 mass% or more and 2.2 mass% or less, more preferably 1.0 mass% or more and 2.0 mass% or less, and still more preferably 1.1 mass% or more and 1.9 mass% or less.

[0070]

<Content of Mo in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 0.0 mass% or more (including 0 mass%) and 2.0 mass% or less>

Mo is a component having an effect of improving the strength of the weld metal, and may be added as necessary. The lower limit of Mo is not particularly required to be specified, and may be 0.0 mass%. In a case where Mo is added to the coating agent and the content of Mo in the coating agent is 2.0 mass% or less, cracks can be further prevented while maintaining the strength. Accordingly, the content of Mo in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 2.0 mass% or less, more preferably 1.2 mass% or less, and still more preferably 0.8 mass% or less.

For the same reason as described above, the content of Mo in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.65 mass% or less (including 0 mass %), more preferably 0.45 mass% or less, and still more preferably 0.30 mass% or less.

[0071]

<Content of Al_2O_3 in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 0.02 mass% or more and 3.0 mass% or less>

Al_2O_3 is a component having an arc stabilizing effect and an effect as a slag forming agent. When the content of Al_2O_3 in the coating agent is 3.0 mass% or less, a higher arc stabilizing effect can be obtained. Accordingly, the content of Al_2O_3 in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 0.02 mass% or more and 3.0 mass% or less, more preferably 0.03 mass% or more and 2.6 mass% or less, and still more preferably 0.05 mass% or more and 2.0 mass% or less.

For the same reason as described above, the content of Al_2O_3 in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.01 mass% or more and 0.90 mass% or less, more preferably 0.02 mass% or more and 0.80 mass% or less, and still more preferably 0.02 mass% or more and 0.70 mass% or less.

5 [0072]

<Content of SiO_2 in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 1.5 mass% or more and 15.0 mass% or less>

SiO_2 is a component acting as a smelting agent or an adhesive. When the content of SiO_2 in the coating agent is 1.5 mass% or more, the above-described effects can be
10 sufficiently obtained. In addition, when the content of SiO_2 in the coating agent is 15.0 mass% or less, the slag peelability is further improved. Accordingly, the content of SiO_2 in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 1.5 mass% or more and 15.0 mass% or less, more preferably 2.0 mass% or more and 10.0 mass% or less, and still more preferably 4.0 mass% or more and 8.0 mass% or less.

15 For the same reason as described above, the content of SiO_2 in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.40 mass% or more and 4.00 mass% or less, more preferably 0.60 mass% or more and 3.60 mass% or less, and still more preferably 0.80 mass% or more and 3.20 mass% or less, relative to the total mass of the covered electrode.

20 [0073]

<Content of TiO_2 in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 0.2 mass% or more and 10.0 mass% or less>

TiO_2 is a component, which has an action of generating slag with good fluidity, giving gloss to a surface of a bead, and giving a beautiful appearance to the weld metal, in the
25 coating agent of the covered electrode. In addition, TiO_2 is also a component that contributes to preventing deflection (fluctuation) of an arc and obtaining good weldability. When the content of TiO_2 in the coating agent relative to the total mass of the coating agent is within a range of 0.2 mass% or more and 10.0 mass% or less, the effects described above are further improved. Accordingly, the content of TiO_2 in the coating agent relative to the total
30 mass of the coating agent ($C_{\text{coat, total}}$) is preferably 0.2 mass% or more and 10.0 mass% or less, more preferably 0.5 mass% or more and 8.0 mass% or less, and still more preferably 1.0 mass% or more and 6.0 mass% or less.

For the same reason as described above, the content of TiO_2 in the covered

electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 1.00 mass% or more and 4.00 mass% or less, more preferably 1.20 mass% or more and 3.00 mass% or less, and still more preferably 1.40 mass% or more and 2.60 mass% or less.

[0074]

<Content of MgO in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): more than 0.01 mass% and 4.0 mass% or less>

MgO is a component having an effect of increasing the peelability of slag. When the content of MgO in the coating agent is more than 0.01 mass% and 4.0 mass% or less, the above-described effects are further improved. Accordingly, the content of MgO in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably more than 0.01 mass% and 4.0 mass% or less, more preferably 0.2 mass% or more and 1.0 mass% or less, and still more preferably 0.5 mass% or more and 0.8 mass% or less.

For the same reason as described above, the content of MgO in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.01 mass% or more and 1.00 mass% or less, more preferably 0.01 mass% or more and 0.80 mass% or less, and still more preferably 0.01 mass% or more and 0.50 mass% or less.

[0075]

<Total content of K_2O , Li_2O and Na_2O in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 1.6 mass% or more and 3.6 mass% or less>

K_2O , Li_2O and Na_2O are components contained in a large amount in water glass used as an inorganic binder in the coating agent, are also added as powder raw materials, and are effective components for improving the arc stability by obtaining good arc stability and an appropriate arc force. In order to further enhance the above-described effects, the total content of K_2O , Li_2O and Na_2O in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 1.6 mass% or more and 3.6 mass% or less, more preferably 1.8 mass% or more and 3.2 mass% or less, and still more preferably 2.0 mass% or more and 3.0 mass% or less.

For the same reason as described above, the total content of K_2O , Li_2O and Na_2O in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.20 mass% or more and 1.40 mass% or less, more preferably 0.40 mass% or more and 1.20 mass% or less, and still more preferably 0.60 mass% or more and 1.00 mass% or less.

In addition, Li_2O also has an effect of improving moisture absorption resistance of

the covered electrode and reducing diffusible hydrogen in the weld metal.

[0076]

<Content of C in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$): 0.0 mass% or more (including 0 mass%) and 0.15 mass% or less>

5 C is a component contributing to the improvement of the strength of the weld metal, and may be added as necessary. The lower limit of C is not particularly required to be specified, and may be 0.0 mass%. In a case where C is added to the coating agent, the content of C is preferably 0.15 mass% or less in order to prevent a decrease in ductility of the weld metal and a crack. Accordingly, the content of C in the coating agent relative to the
10 total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 0.0 mass% or more and 0.15 mass% or less. From the viewpoint of improving the weldability, the content of C is more preferably 0.01 mass% or more and 0.10 mass% or less, and still more preferably 0.02 mass% or more and 0.08 mass% or less. Examples of the C source include organic substances, various minerals, alloying agents, graphite, and the like.

15 For the same reason as described above, the content of C in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$) is preferably 0.15 mass% or less (including 0 mass%), more preferably 0.01 mass% or more and 0.10 mass% or less, and still more preferably 0.02 mass% or more and 0.08 mass% or less.

[0077]

20 <Remainder>

The remainder of the coating agent in the present embodiment is inevitable impurities. Examples of the inevitable impurities include Nb_2O_5 , V_2O_5 , ZrO_2 , $\text{Fe}_2\text{O}_3\cdot\text{FeO}$, SnO , P, S, and the like. The total content of the inevitable impurities in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is preferably 5.0 mass% or less
25 (including 0 mass%). In addition, it is more preferable that the content of Nb_2O_5 in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is limited to 0.3 mass% or less (including 0 mass%), the content of V_2O_5 is limited to 0.3 mass% or less (including 0 mass%), the content of ZrO_2 is limited to 0.4 mass% or less (including 0 mass%), and the content of $\text{Fe}_2\text{O}_3\cdot\text{FeO}$ is limited to 3.50 mass% or less (including 0 mass%). Note that the
30 meaning of the impurities also includes those that are not intended in the design of the electrode. For example, illuminite raw materials are added to a coating agent in an illuminite-based covered electrode, and thus, $\text{Fe}_2\text{O}_3\cdot\text{FeO}$ unintended in the design of the electrode may be contained in an amount of 3.50 mass% at the maximum, and these are

defined as impurities.

[0078]

Next, a core wire and a coating ratio are described.

[0079]

5 [Core Wire]

The core wire in the present embodiment is not particularly limited, and for example, a core wire having a diameter d of 2.6 mm to 6.0 mm may be used, and a core wire having a diameter of 4.0 mm can be particularly preferably used. The composition of the core wire in the present embodiment is described below.

10 [0080]

<Content of O: 0.0005 mass% or more and 0.0150 mass% or less>

When the content of O in the core wire is excessive, the amount of O in the obtained weld metal becomes excessive, and the toughness of the weld metal may decrease. In addition, since oxygen in the core wire reacts with Fe-Si or Fe-Mn, which is a deoxidizing agent added to the coating agent, to generate slag, the amount of slag is increased, which may cause deterioration of the fluidity of slag and the weldability, and may further cause deterioration of mechanical properties due to a decrease in the amount of Si or Mn in the weld metal or an increase in the amount of oxygen.

15

In addition, the fluidity of the molten metal is increased, and the weld metal is likely to fall during welding in a standing position, an upward position, or the like, and thus, weldability may decrease. On the other hand, when the content of O in the core wire is too small, expansion of the molten pool due to the arc force becomes insufficient, and a weld metal in which alloy components are uniformly distributed cannot be obtained.

20

From the above viewpoint, the content of O in the core wire relative to the total mass of the core wire is preferably 0.0005 mass% or more, more preferably 0.0013 mass% or more, and still more preferably 0.0016 mass% or more. The content of O in the core wire is preferably 0.0150 mass% or less, more preferably 0.0125 mass% or less, and still more preferably 0.0100 mass% or less.

25

[0081]

30 <Other Components>

Although not particularly limited, as the core wire in the present embodiment, for example, an iron-based core wire containing Fe as a main component can be preferably used. Specifically, SWRY11 specified in JIS G 3503: 2006 can be used as the core wire.

In addition to O and Fe, C, Si, Mn, P, S, N, Cu, and the like may be contained in the core wire. It is preferable that the content of C in the core wire relative to the total mass of the core wire is limited to 0.09 mass% or less, the content of Si is limited to 0.03 mass% or less (including 0 mass%), the content of Mn is limited to 0.35 mass% or more and 0.65 mass% or less, the content of P is limited to 0.020 mass% or less (including 0 mass%), the content of S is limited to 0.023 mass% or less (including 0 mass%), and the content of Cu is limited to 0.20 mass% or less (including 0 mass%).

[0082]

[Coating Ratio]

In the present embodiment, a coating ratio of the coating agent on an outer periphery of the core wire is not particularly limited, but is, for example, preferably 20% or more, more preferably 22% or more, and still more preferably 24% or more, from the viewpoint of ensuring the strength of the coating agent. In addition, from the viewpoint of arc stability and the like, the coating ratio is, for example, preferably 40% or less, more preferably 38% or less, and still more preferably 36% or less.

[0083]

The present embodiment also relates to an arc welding method using the covered electrode in which the components in the above-described coating agent are controlled. In the arc welding method in the present embodiment, the reasons for limiting the components (the grain diameter, the area ratio, and the like) in the coating agent of an electrode to be used, the length of the coating agent remaining after arc use, and the like are as described above, and thus description thereof is omitted. Hereinafter, a welding position in the arc welding method in the present embodiment is particularly described.

[0084]

[Welding Position]

<Covered electrode being perpendicular to base metal or having drag angle of more than 0° and 30° or less relative to base metal>

The covered electrode in the present embodiment is preferably used in arc welding in a welding position in which a covered electrode is perpendicular to a base metal (that is, the covered electrode is disposed perpendicular to the base metal) or a drag angle of the covered electrode relative to the base metal is more than 0° and 30° or less. As described above, welding using a covered electrode is often performed in various welding positions such as a push angle and a drag angle, and in a case where welding is performed in these welding

positions (that is, in a case where the covered electrode is appropriately inclined), one-sided melting remarkably occurs as compared with a case where a covered electrode is perpendicular to a base metal. In shielded metal arc welding in the case of a drag angle of more than 0° and 30° or less, the covered electrode in the present embodiment can obtain substantially the same effect as in the case where the covered electrode is perpendicular to the base metal. The above-described drag angle is more preferably 5° or more and 25° or less.

Even in a case where the welding position is perpendicular, the molten pool itself may not be horizontal relative to the base metal in some cases. However, the covered electrode in the present embodiment has high robustness and can prevent one-sided melting even if some disturbance or error occurs.

[0085]

The covered electrode in the present embodiment can be applied as an electrode based on various kinds of electrodes, such as an illuminite-based electrode, a high titanium oxide-based electrode, a lime titania-based electrode, an iron powder titanium oxide-based electrode, a high cellulose-based electrode, a low hydrogen-based electrode, and an iron powder low hydrogen-based electrode. Since a large amount of the gas generating agent is added to a coating agent in the low hydrogen-based electrode for the purpose of reducing diffusible hydrogen, an effect of releasing droplets by the gas generating agent becomes remarkable when the covered electrode in the present embodiment is applied to the low hydrogen-based electrode.

Further, a large amount of iron powder is added to a coating agent in an iron powder low hydrogen-based electrode for the purpose of obtaining a desired amount of weld metal, and the iron powder causes the droplets to grow greatly. Thus, there is a problem that smooth droplet transferability cannot be obtained and large spatters are scattered.

Accordingly, it is most preferable that the covered electrode in the present embodiment, by which droplet releasability can be improved, is applied as an iron powder low hydrogen-based electrode.

[0086]

The production method of the covered electrode described above is not particularly limited. For example, the covered electrode in the present embodiment can be produced by kneading a coating agent raw material together with water glass, applying the resultant mixture to an outer periphery of a core wire, and performing drying and firing.

Examples

[0087]

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

5 [0088]

[Production of Covered Electrode, Arc Welding, and Calculation of Various Parameters]

SWRY 11 having a diameter of 3.2 to 5.0 mm were prepared as a core wire, and coating agents (coating agents Nos. C1 to C15) having a chemical composition shown in Table 1 were applied to outer peripheries of the core wires at coating ratios of 26.9% to 35.6% as shown in Table 3, respectively, followed by drying to produce various covered electrodes (Test Nos. T1 to T19 shown in Table 3).

[0089]

Table 1 shows a content of each component in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$). In Table 1, the remainder is inevitable impurities, and the amount of each component in the coating agent indicates the content (mass%) relative to the total mass of the coating agent ($C_{\text{coat, total}}$).

Table 4 shows the content of each component in the covered electrode relative to the total mass of the covered electrode ($C_{\text{electrode, total}}$). In Table 4, the remainder is inevitable impurities, and the amount (mass%) of each component in the covered electrode indicates the content (mass%) relative to the total mass of the electrode ($C_{\text{electrode, total}}$).

[0090]

Further, Table 2 shows a list of various physical property values relating to a content of a metal carbonate contained in a coating agent or a content of a metal fluoride contained in a coating agent.

In Table 2, $C[\text{CO}_2, 75 \mu\text{m}]$ refers to a total content (CO_2 conversion value) of a metal carbonate having a grain diameter of 75 μm or more, $C[\text{F}, 75 \mu\text{m}]$ refers to a total content (F conversion value) of a metal fluoride having a grain diameter of 75 μm or more, $C[\text{CO}_2, 106 \mu\text{m}]$ refers to a total content (CO_2 conversion value) of a metal carbonate having a grain diameter of 106 μm or more, $C[\text{F}, 106 \mu\text{m}]$ refers to a total content (F conversion value) of a metal fluoride having a grain diameter of 106 μm or more, $C[\text{CO}_2, 150 \mu\text{m}]$ refers to a total content (CO_2 conversion value) of a metal carbonate having a grain diameter of 150 μm or more, and $C[\text{F}, 150 \mu\text{m}]$ refers to a total content (F conversion value) of a metal fluoride having a grain diameter of 150 μm or more.

In addition, $C[\text{CO}_2, \text{total}]$ refers to a total content (CO_2 conversion value) of metal carbonates contained in the coating agent, and $C[\text{F}, \text{total}]$ refers to a total content (F conversion value) of metal fluorides contained in the coating agent. $C[\text{coat}, \text{total}]$ refers to a total mass of the coating agent, and $C[\text{Si}, \text{total}]$ refers to a total content (Si conversion value) of Si and a Si compound.

[0091]

Here, for example, $C[\text{CO}_2, 75 \mu\text{m}]/C[\text{CO}_2, \text{total}]$ shown in the column (1) in Table 2 indicates a ratio of the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $75 \mu\text{m}$ or more ($C_{\text{CO}_2, 75 \mu\text{m}}$) relative to the total content (CO_2 conversion value) of the metal carbonates contained in the coating agent ($C_{\text{CO}_2, \text{total}}$). The same applies to other columns.

[0092]

In addition, “(5) + (6)” shown in the column (7) in Table 2 indicates a total amount of $C[\text{CO}_2, 75 \mu\text{m}]/C[\text{coat}, \text{total}]$ shown in the column (5) and $C[\text{F}, 75 \mu\text{m}]/C[\text{coat}, \text{total}]$ shown in the column (6), that is, a total amount of a ratio of the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $75 \mu\text{m}$ or more ($C_{\text{CO}_2, 75 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat}, \text{total}}$) and a ratio of the content (F conversion value) of the metal fluoride having a grain diameter of $75 \mu\text{m}$ or more ($C_{\text{F}, 75 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat}, \text{total}}$). Similarly, “(8) + (9)” shown in the column (10) in Table 2 indicates a total amount of a ratio of the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $106 \mu\text{m}$ or more ($C_{\text{CO}_2, 106 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat}, \text{total}}$) and a ratio of the content (F conversion value) of the metal fluoride having a grain diameter of $106 \mu\text{m}$ or more ($C_{\text{F}, 106 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat}, \text{total}}$). Similarly, “(11) + (12)” shown in the column (13) in Table 2 indicates a total amount of a ratio of the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $150 \mu\text{m}$ or more ($C_{\text{CO}_2, 150 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat}, \text{total}}$) and a ratio of the content (F conversion value) of the metal fluoride having a grain diameter of $150 \mu\text{m}$ or more ($C_{\text{F}, 150 \mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat}, \text{total}}$).

[0093]

Subsequently, arc welding was performed using the obtained covered electrode under the following welding conditions, and the power supply was optionally turned off after 10 seconds from the start of welding. As shown in Table 5, in Test Nos. T9 and T10, tests

were performed with variously changing a drag angle within a range of 5° to 25°. In test examples other than Test Nos. T9 and T10, tests were performed with the drag angle being fixed to 15°.

[0094]

5

<Welding Conditions>

Polarity of power supply: DCEP

Welding position: downward bead on plate

Welding object: SM490 steel sheet of 12 mmt × 70 mmt × 450 mml

Welding current: 150 A (target) ± 10 A

10

Arc voltage: 21 V (target) ± 2 V

[0095]

15

Thereafter, a length from the most distal end portion of the coating agent (protective sheath) remaining around the core wire on an electrode distal end side to an electrode rear end portion on a holder side (rear end side) was measured, and a length from the rearmost portion of the coating agent (protective sheath) remaining around the core wire on the electrode distal end side to the electrode rear end portion on the holder side was measured.

20

Further, the coating agent forming the protective sheath and slag remaining on an end portion of the core wire were removed, and a length from the distal end portion of the core wire to the electrode rear end portion on the holder side was measured. Then, these measured values were used to calculate a distance D1 between the distal end portion of the core wire and the most distal end portion of the coating agent remaining around the core wire in the longitudinal direction of the electrode, and a distance D2 between the most distal end portion of the coating agent remaining around the core wire and the rearmost portion of the coating agent remaining around the core wire in the longitudinal direction of the electrode (see Table 5).

25

[0096]

30

The covered electrode obtained by the above-described method was embedded in a resin such that a cross section perpendicular to the longitudinal direction served as an observation surface, and was observed with a scanning electron microscope (SEM). The observation based on SEM was performed by using a backscattered electron (BSE) image at a magnification of 50 times and an acceleration voltage of 15 kV.

Then, the cross section of the coating agent was subjected to elemental analysis using energy dispersive X-ray spectroscopy (EDX), and an area ratio of grains with an

equivalent circle diameter of 30 μm or more, that is, a ratio of S_2 to S_1 (S_2/S_1) was calculated, in which S_1 was a cross-sectional area of the entire coating agent and S_2 was a total area of at least one of the metal carbonate and the metal fluoride, each having an equivalent circle diameter of 30 μm or more.

5 [0097]

EDX analysis based on SEM can be performed as follows. For example, using TM3030 Miniscope manufactured by Hitachi High-Tech Corporation, the cross section of the covered electrode is analyzed (magnification: 50 times, four rectangular regions of 1.61 mm $\times$ 1.21 mm). The field of view is desirably selected such that the cross section of the coating agent is 70% or more in each field of view. Then, by binarizing 1024 $\times$ 768 pixels (the number of pixels: 786432) relative to one field of view using image analysis software Image J, an area ratio of grains having an area of 706.8 μm^2 or more (equivalent circle diameter: 30 μm or more) can be calculated. The threshold value during binarization is, for example, 60.

10 [0098]

15 The measurement results of the diameter d of the core wire and S_2/S_1 in the covered electrode are shown in Table 3 below. The measurement results of D_2/D_1 , D_1 , and D_1/d are shown in Table 5 below.

[0099]

Further, the covered electrodes of Test Nos. T1 to T15 (Examples) and Test Nos. T16 to T19 (Comparative Examples) were used for welding under the same welding conditions during measurement of the above D_1 and D_2 , and were evaluated in term of the one-sided melting evaluation (presence or absence of one-sided melting), the effect of preventing the arc deflection, and the weldability in accordance with the following evaluation criteria.

25 [0100]

[One-side Melting Evaluation (Presence or Absence of One-side Melting)]

In a case where $D_2/D_1 \leq 0.40$ is satisfied: absent

In a case where $D_2/D_1 > 0.40$ is satisfied: present

[0101]

30 [Effect of Preventing Arc Deflection]

The presence or absence of deflection of an arc and an appearance of a bead were visually evaluated. The case of determining that the arc was not deflected and the appearance of the bead was good was evaluated as $\circ\circ$ (excellent), the case of determining

that the arc was slightly deflected, but the appearance of the bead was good was evaluated as ○ (good), and the case of determining that the arc was deflected and the appearance of the bead was poor was evaluated as × (poor).

[0102]

5 [Weldability (Sensory Evaluation)]

The case of visually determining that droplets were periodically transferred during welding and only fine spatter was generated was evaluated as ○○ (excellent), the case of determining that droplets were periodically transferred during welding, but medium-grain spatter was generated visually was evaluated as ○ (good), and the case of determining that

10 droplets were not periodically transferred during welding and a large amount of large-grain spatter was generated was evaluated as × (poor).

[0103]

Table 1

Coating agent No.	Content of each component in coating agent relative to total mass of coating agent ($C_{\text{coat, total}}$) (mass%)																	
	Metal carbonate				Metal fluoride		Si	Mn	Fe	SiO ₂	Al ₂ O ₃	TiO ₂	MgO	Na ₂ O ⁺ K ₂ O ⁺ Li ₂ O	C	Ni	Mo	Al
	CaCO ₃	BaCO ₃	Total	Total CO ₂ conversion value	CaF ₂	F conversion value												
C1	53.5	0.0	53.5	23.5	17.1	8.3	6.60	2.44	9.3	5.87	0.22	0.79	0.00	2.41	0.06	0.00	0.000	0.124
C2	43.2	9.2	52.4	21.1	16.7	8.1	5.08	1.98	7.2	7.35	0.08	5.74	0.26	2.78	0.05	0.00	0.000	0.095
C3	51.2	3.8	55.0	23.4	16.3	7.9	5.74	2.91	8.3	1.74	0.47	6.19	0.53	2.61	0.07	0.00	0.000	0.108
C4	47.0	0.0	47.0	20.7	6.7	3.3	4.51	4.68	7.0	14.13	2.58	8.07	0.00	2.79	0.05	0.00	0.000	0.083
C5	53.7	0.0	53.7	23.6	0.0	0.0	6.36	1.85	19.7	6.05	0.28	5.82	0.33	2.00	0.05	0.00	0.000	0.119
C6	32.1	0.0	32.1	14.1	12.2	5.9	3.68	3.06	27.8	6.43	0.28	5.46	1.13	2.62	0.04	1.21	0.557	0.148
C7	32.0	0.0	32.0	14.1	12.1	5.9	3.67	3.05	27.7	6.42	0.60	5.44	1.13	2.62	0.04	1.21	0.555	0.148
C8	32.1	0.0	32.1	14.1	12.2	5.9	3.68	3.06	27.8	6.37	0.28	5.46	1.13	2.69	0.04	1.21	0.557	0.148
C9	32.0	0.0	32.0	14.1	12.1	5.9	3.67	3.05	27.7	6.36	0.60	5.44	1.13	2.69	0.04	1.21	0.555	0.148
C10	32.0	0.0	32.0	14.1	12.1	5.9	3.67	3.05	27.7	6.36	0.60	5.44	1.13	2.69	0.04	1.21	0.555	0.148
C11	32.6	0.0	32.6	14.4	12.2	5.9	3.74	3.11	28.3	6.61	0.30	5.55	0.39	2.62	0.04	1.23	0.567	0.233
C12	27.3	0.0	27.3	12.0	1.5	0.7	2.73	7.00	4.8	5.43	1.32	41.16	0.22	2.84	0.06	0.00	0.000	0.049
C13	28.1	1.9	30.0	12.8	15.6	7.6	3.38	2.76	28.6	6.68	0.80	6.66	0.21	3.05	0.07	0.00	0.000	0.062
C14	24.0	0.0	24.0	10.6	19.3	9.4	3.28	2.47	33.0	5.55	0.30	6.06	0.47	2.86	0.06	0.00	0.000	0.157
C15	26.7	0.0	26.7	11.7	17.8	8.7	3.82	3.18	28.8	6.19	0.25	5.67	0.39	2.62	0.04	1.26	0.578	0.154

[0104]

Table 2

Coating agent No.	Various physical property values relating to content of metal carbonate or content of metal fluoride contained in coating agent (mass%)														
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	C[CO ₂ , 75 μm]/ C[CO ₂ , total]	C[F, 75 μm]/ C[F, total]	C[CO ₂ , total]/ C[coat, total]	C[F, total]/ C[coat, total]	C[CO ₂ , 75 μm]/ C[coat, total]	C[F, 75 μm]/ C[coat, total]	(5) + (6)	C[CO ₂ , 106 μm]/ C[coat, total]	C[F, 106 μm]/ C[coat, total]	(8) + (9)	C[CO ₂ , 150 μm]/ C[coat, total]	C[F, 150 μm]/ C[coat, total]	(11) + (12)	C[F, total]/ {C[CO ₂ , total] + C[F, total]}	C[Si, total]/ C[coat, total]
C1	33.8	33.0	23.5	8.3	7.9	2.8	10.7	5.8	2.3	8.1	3.1	1.6	4.7	0.26	9.34
C2	34.8	28.3	21.1	8.1	7.3	2.3	9.6	5.3	1.8	7.1	2.9	1.2	4.1	0.28	8.52
C3	42.9	21.4	23.4	7.9	10.0	1.7	11.7	7.3	1.2	8.5	3.9	0.7	4.6	0.25	6.55
C4	32.5	23.1	20.7	3.3	6.7	0.8	7.5	4.9	0.5	5.4	2.6	0.3	2.9	0.14	11.11
C5	40.5	0.0	23.6	0.0	9.6	0.0	9.6	6.9	0.0	6.9	3.8	0.0	3.8	0.00	9.18
C6	32.4	43.2	14.1	5.9	4.6	2.6	7.2	3.3	2.3	5.6	1.8	1.7	3.5	0.30	6.69
C7	32.4	43.2	14.1	5.9	4.6	2.5	7.1	3.3	2.3	5.6	1.8	1.7	3.5	0.30	6.67
C8	32.4	43.2	14.1	5.9	4.6	2.6	7.2	3.3	2.3	5.6	1.8	1.7	3.5	0.30	6.66
C9	32.4	43.2	14.1	5.9	4.6	2.5	7.1	3.3	2.3	5.6	1.8	1.7	3.5	0.30	6.64
C10	32.5	43.3	14.1	5.9	4.6	2.6	7.2	3.3	2.3	5.6	1.8	1.7	3.5	0.30	6.64
C11	40.5	52.9	14.4	5.9	5.8	3.1	8.9	4.2	3.0	7.2	2.3	2.3	4.6	0.29	6.83
C12	29.0	22.9	12.0	0.7	3.5	0.2	3.7	2.5	0.1	2.6	1.4	0.1	1.5	0.06	5.26
C13	27.0	23.1	12.8	7.6	3.5	1.8	5.3	2.5	1.2	3.7	1.4	0.7	2.1	0.37	6.50
C14	35.4	23.1	10.6	9.4	3.7	2.2	5.9	2.8	1.5	4.3	1.5	0.9	2.4	0.47	5.88
C15	16.2	23.0	11.7	8.7	1.9	2.0	3.9	1.4	1.4	2.8	0.7	0.8	1.5	0.42	6.71

[0105]

Table 3

Test No.	Covered electrode				Reference
	Coating agent	Coating ratio	Diameter d of core wire in covered electrode	S ₂ /S ₁	
	Coating agent No.	Mass%	mm	-	
T1	C1	30.0	4.0	0.087	Example
T2	C2	30.0	4.0	0.077	Example
T3	C3	27.0	4.0	0.078	Example
T4	C4	26.9	4.0	0.068	Example
T5	C5	27.6	4.0	0.077	Example
T6	C6	35.0	4.0	0.064	Example
T7	C7	35.0	4.0	0.081	Example
T8	C8	35.0	4.0	0.079	Example
T9	C9	35.0	4.0	0.087	Example
T10	C10	35.0	4.0	0.079	Example
T11	C11	35.0	4.0	0.110	Example
T12	C1	31.0	3.2	0.086	Example
T13	C2	30.0	3.2	0.070	Example
T14	C4	26.9	3.2	0.068	Example
T15	C3	28.0	5.0	0.078	Example
T16	C12	35.6	4.0	0.059	Comparative Example
T17	C13	34.0	4.0	0.059	Comparative Example
T18	C14	35.0	4.0	0.078	Comparative Example
T19	C15	35.0	4.0	0.055	Comparative Example

[0106]

Table 4

Test No.	Content of each component in covered electrode relative to total mass of covered electrode ($C_{\text{electrode, total}}$) (mass%)																	Reference	
	Metal carbonate				Metal fluoride		Si	Mn	Fe	SiO ₂	Al ₂ O ₃	TiO ₂	MgO	Na ₂ O ⁺ K ₂ O ⁺ Li ₂ O	C	Ni	Mo		Al
	CaCO ₃	BaCO ₃	Total	Total CO ₂ conversion value	CaF ₂	F conversion value													
T1	16.0	0.0	16.0	7.1	5.1	2.5	2.0	1.0	72.5	1.76	0.07	0.24	0.00	0.72	0.06	0.00	0.00	0.04	Example
T2	13.0	2.8	15.7	6.3	5.0	2.4	1.5	0.9	71.8	2.20	0.02	1.72	0.08	0.83	0.06	0.00	0.00	0.03	Example
T3	13.8	1.0	14.8	6.3	4.4	2.1	1.6	1.1	74.9	0.47	0.13	1.67	0.14	0.70	0.06	0.00	0.00	0.03	Example
T4	12.6	0.0	12.6	5.6	1.8	0.9	1.2	1.6	74.7	3.80	0.69	2.17	0.00	0.75	0.06	0.00	0.00	0.02	Example
T5	14.8	0.0	14.8	6.5	0.0	0.0	1.8	0.8	77.5	1.67	0.08	1.61	0.09	0.55	0.06	0.00	0.00	0.03	Example
T6	11.2	0.0	11.2	4.9	4.3	2.1	1.3	1.3	74.4	2.25	0.10	1.91	0.40	0.92	0.05	0.42	0.19	0.05	Example
T7	11.2	0.0	11.2	4.9	4.2	2.1	1.3	1.3	74.4	2.25	0.21	1.90	0.40	0.92	0.05	0.42	0.19	0.05	Example
T8	11.2	0.0	11.2	4.9	4.3	2.1	1.3	1.3	74.4	2.23	0.10	1.91	0.40	0.94	0.05	0.42	0.19	0.05	Example
T9	11.2	0.0	11.2	4.9	4.2	2.1	1.3	1.3	74.4	2.23	0.21	1.90	0.40	0.94	0.05	0.42	0.19	0.05	Example
T10	11.2	0.0	11.2	4.9	4.2	2.1	1.3	1.3	74.4	2.23	0.21	1.90	0.40	0.94	0.05	0.42	0.19	0.05	Example
T11	11.4	0.0	11.4	5.0	4.3	2.1	1.3	1.4	74.6	2.31	0.11	1.94	0.13	0.92	0.05	0.43	0.20	0.08	Example
T12	16.4	0.0	16.4	7.2	5.3	2.6	2.0	1.0	71.5	1.99	0.11	0.28	0.00	0.78	0.06	0.00	0.00	0.04	Example

Table 4 (continued)

Test No.	Content of each component in covered electrode relative to total mass of covered electrode ($C_{\text{electrode, total}}$) (mass%)																		Reference
	Metal carbonate				Metal fluoride		Si	Mn	Fe	SiO ₂	Al ₂ O ₃	TiO ₂	MgO	Na ₂ O ⁺ K ₂ O ⁺ Li ₂ O	C	Ni	Mo	Al	
	CaCO ₃	BaCO ₃	Total	Total CO ₂ conversion value	CaF ₂	F conversion value													
T13	12.8	2.7	15.6	6.3	5.1	2.5	1.5	0.9	71.8	1.95	0.05	1.72	0.36	0.85	0.06	0.00	0.00	0.03	Example
T14	12.7	0.0	12.7	5.6	1.8	0.9	1.2	1.6	74.7	3.82	0.69	2.17	0.00	0.69	0.06	0.00	0.00	0.02	Example
T15	14.3	1.1	15.4	6.5	4.6	2.2	1.6	1.1	74.0	0.49	0.13	1.73	0.15	0.73	0.06	0.00	0.00	0.03	Example
T16	9.7	0.0	9.7	4.3	0.5	0.3	1.0	2.8	65.8	1.93	0.47	14.65	0.08	1.01	0.06	0.00	0.00	0.02	Comparative Example
T17	9.6	0.6	10.2	4.3	5.3	2.6	1.2	1.2	75.4	2.27	0.27	2.26	0.07	1.04	0.06	0.00	0.00	0.02	Comparative Example
T18	8.4	0.0	8.4	3.7	6.7	3.3	1.2	1.1	76.3	1.94	0.11	2.12	0.16	1.00	0.06	0.00	0.00	0.05	Comparative Example
T19	9.3	0.0	9.3	4.1	6.2	3.0	1.3	1.4	74.8	2.17	0.09	1.98	0.14	0.92	0.05	0.44	0.20	0.05	Comparative Example

[0107]

Table 5

Test No.	Welding conditions	Evaluation						Reference
	Welding position and angle	One-sided melting evaluation				Effect of preventing arc deflection	Weldability	
		D ₂ /D ₁	Presence or absence of one-sided melting	D ₁	D ₁ /d			
		-	-	-	mm			
T1	Drag angle: 15°	0.22	Absent	2.9	0.7	○○	○	Example
T2	Drag angle: 15°	0.36	Absent	1.6	0.4	○	○	Example
T3	Drag angle: 15°	0.32	Absent	2.6	0.7	○	○	Example
T4	Drag angle: 15°	0.25	Absent	2.1	0.5	○○	○	Example
T5	Drag angle: 15°	0.35	Absent	2.8	0.7	○	○	Example
T6	Drag angle: 15°	0.18	Absent	2.8	0.7	○○	○	Example
T7	Drag angle: 15°	0.12	Absent	1.5	0.4	○○	○○	Example
T8	Drag angle: 15°	0.21	Absent	1.3	0.3	○○	○○	Example
T9	Drag angle: 5°	0.10	Absent	2.0	0.5	○○	○○	Example
	Drag angle: 10°	0.26	Absent	1.9	0.5	○○	○○	Example
	Drag angle: 15°	0.23	Absent	2.0	0.5	○○	○○	Example
	Drag angle: 20°	0.24	Absent	1.9	0.5	○○	○○	Example
	Drag angle: 25°	0.33	Absent	2.0	0.5	○○	○○	Example

Table 5 (continued)

Test No.	Welding conditions	Evaluation						Reference
	Welding position and angle	One-sided melting evaluation				Effect of preventing arc deflection	Weldability	
		D ₂ /D ₁	Presence or absence of one-sided melting	D ₁	D ₁ /d			
	-	-	-	mm	-	-	-	
T10	Drag angle: 5°	0.23	Absent	1.6	0.4	○○	○○	Example
	Drag angle: 10°	0.15	Absent	2.0	0.5	○○	○○	Example
	Drag angle: 15°	0.24	Absent	1.9	0.5	○○	○○	Example
	Drag angle: 20°	0.29	Absent	1.7	0.4	○○	○○	Example
	Drag angle: 25°	0.39	Absent	1.9	0.5	○○	○○	Example
T11	Drag angle: 15°	0.28	Absent	1.6	0.4	○○	○	Example
T12	Drag angle: 15°	0.34	Absent	3.6	1.1	○	○	Example
T13	Drag angle: 15°	0.28	Absent	3.6	1.1	○○	○	Example
T14	Drag angle: 15°	0.11	Absent	2.1	0.7	○○	○	Example
T15	Drag angle: 15°	0.36	Absent	4.1	0.8	○	○	Example
T16	Drag angle: 15°	0.42	Present	1.2	0.3	×	×	Comparative Example
T17	Drag angle: 15°	0.42	Present	2.4	0.6	×	×	Comparative Example
T18	Drag angle: 15°	0.60	Present	1.8	0.5	×	×	Comparative Example
T19	Drag angle: 15°	0.62	Present	1.4	0.4	×	×	Comparative Example

[0108]

Tests Nos. T1 to T15 (Examples) in Tables 3 to 5 are the cases using the coating agents Nos. C1 to C11 in Table 1 or Table 2, which satisfy the requirements of the present invention (that is, the total of the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $75\text{ }\mu\text{m}$ or more ($C_{\text{CO}_2, 75\text{ }\mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) and the content (F conversion value) of the metal fluoride having a grain diameter of $75\text{ }\mu\text{m}$ or more ($C_{\text{F, } 75\text{ }\mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more) (see column (7) in Table 2). For these Test Nos. T1 to T15 as shown in Table 5, $D_2/D_1 \leq 0.40$ (no one-sided melting) was satisfied, and excellent or good results were obtained in all of the effect of preventing arc deflection and the weldability.

[0109]

In contrast, Test Nos. T16 to T19 (Comparative Examples) in Tables 3 to 5 are the cases using the coating agents Nos. C12 to C15 in Table 1 or Table 2, which do not satisfy the requirements of the present invention (see column (7) in Table 2). For these Test Nos. T16 to T19 as shown in Table 5, $D_2/D_1 \leq 0.40$ was not satisfied (one-sided melting occurred), and poor results were obtained in either of the effect of preventing arc deflection and the weldability.

[0110]

As described above in detail, as to the covered electrode of the present invention, it is found that, by preventing one-sided melting and inhibiting deflection of an arc, droplets can be smoothly transferred and the arc stability is good, thereby obtaining excellent weldability.

[0111]

Although the embodiments are described above with reference to the drawings, it is needless to say that the present invention is not limited to such examples. It will be apparent to those skilled in the art that various changes and modifications may be conceived within the scope of the claims. It is also found 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.

[0112]

The present application is based on Japanese Patent Application No. 2018-170066 filed on September 11, 2018, and the contents thereof are incorporated herein by reference.

REFERENCE SIGN LIST

[0113]

- | | | |
|----|----------------|---|
| | 1, 11 | Covered electrode |
| | 2 | Core wire |
| 5 | 2a | Distal end portion |
| | 3, 13 | Coating agent |
| | 3a | Distal end |
| | 4, 14 | Arc |
| | 5 | Base metal |
| 10 | 6, 16 | Protective sheath |
| | 13a | Most distal end portion |
| | 13b | Rearmost portion |
| | d | Diameter of core wire in covered electrode |
| | D | Distance between distal end of protective sheath and distal end portion of core wire |
| 15 | | in longitudinal direction of electrode |
| | D ₁ | Distance between distal end portion of core wire and most distal end portion of coating agent remaining around core wire in longitudinal direction of electrode |
| | D ₂ | Distance between most distal end portion of coating agent remaining around core wire and rearmost portion of coating agent remaining around core wire in longitudinal |
| 20 | | direction of electrode |

CLAIMS

[Claim 1]

A covered electrode comprising:

a core wire; and

a coating agent that covers the core wire,

wherein the coating agent contains at least one of a metal carbonate and a metal fluoride,

a total of a content (CO₂ conversion value) of a metal carbonate having a grain diameter of 75 μm or more ($C_{CO_2, 75 \mu m}$) and a content (F conversion value) of a metal fluoride having a grain diameter of 75 μm or more ($C_{F, 75 \mu m}$) relative to a total mass of the coating agent ($C_{coat, total}$) is 6.0 mass% or more (where a case of at least one of the $C_{CO_2, 75 \mu m}$ and the $C_{F, 75 \mu m}$ being 0 mass% is included),

a content of C in the coating agent relative to the total mass of the coating agent ($C_{coat, total}$) is 0.01 mass% or more and 0.15 mass% or less,

the content (CO₂ conversion value) of the metal carbonate having a grain diameter of 75 μm or more ($C_{CO_2, 75 \mu m}$) relative to the total mass of the coating agent ($C_{coat, total}$) is 4.6 mass% or more, and

a total of a content (CO₂ conversion value) of a metal carbonate having a grain diameter of 150 μm or more ($C_{CO_2, 150 \mu m}$) and a content (F conversion value) of a metal fluoride having a grain diameter of 150 μm or more ($C_{F, 150 \mu m}$) relative to the total mass of the coating agent ($C_{coat, total}$) is 2.5 mass% or more and 4.0 mass% or less.

[Claim 2]

The covered electrode according to claim 1,

wherein in a cross section perpendicular to a longitudinal direction of the electrode,

a ratio of S₂ to S₁ (S_2/S_1) satisfies 0.06 or more and 0.15 or less,

wherein S₁ is a cross-sectional area of the entire coating agent, and

S₂ is a total area of at least one of the metal carbonate and the metal fluoride, each having an equivalent circle diameter of 30 μm or more.

[Claim 3]

The covered electrode according to claim 1 or 2,

wherein the coating agent contains at least one selected from CaCO₃, BaCO₃, SrCO₃, MgCO₃ and MnCO₃ as the metal carbonate, and

a total content (CO₂ conversion value) of the metal carbonate in the coating agent (C_{CO₂, total}) relative to the total mass of the coating agent (C_{coat, total}) satisfies 6.0 mass% or more and 26.0 mass% or less.

[Claim 4]

The covered electrode according to any one of claims 1 to 3,
wherein the coating agent contains at least one selected from CaF₂, BaF₂, SrF₂ and MgF₂ as the metal fluoride, and

a total content (F conversion value) of the metal fluoride in the coating agent (C_{F, total}) relative to the total mass of the coating agent (C_{coat, total}) is 15.0 mass% or less (including 0 mass%).

[Claim 5]

The covered electrode according to any one of claims 1 to 4,
wherein the coating agent contains both the metal carbonate and the metal fluoride,
and

a ratio of a total content (F conversion value) of the metal fluoride in the coating agent (C_{F, total}) relative to a total of a total content (CO₂ conversion value) of the metal carbonate in the coating agent (C_{CO₂, total}) and the total content (F conversion value) of the metal fluoride (C_{F, total}) in the coating agent $\{C_{F, total} / (C_{CO_2, total} + C_{F, total})\}$ satisfies 0.10 or more and 0.30 or less.

[Claim 6]

The covered electrode according to any one of claims 1 to 5,
wherein the coating agent further contains at least one of Si and a Si compound, and
a total content (Si conversion value) of the Si and the Si compound (C_{Si, total}) relative to the total mass of the coating agent (C_{coat, total}) is 6.0 mass% or more and 9.0 mass% or less.

[Claim 7]

A shielded metal arc welding method using a covered electrode including a core wire
and a coating agent that covers the core wire,

wherein the coating agent contains at least one of a metal carbonate and a metal fluoride,

a total of a content (CO₂ conversion value) of a metal carbonate having a grain diameter of 75 μm or more (C_{CO₂, 75 μm}) and a content (F conversion value) of a metal fluoride

having a grain diameter of $75\text{ }\mu\text{m}$ or more ($C_{F, 75\text{ }\mu\text{m}}$) relative to a total mass of the coating agent ($C_{\text{coat, total}}$) is 6.0 mass% or more (where a case of at least one of the $C_{\text{CO}_2, 75\text{ }\mu\text{m}}$ and the $C_{F, 75\text{ }\mu\text{m}}$ being 0 mass% is included),

a content of C in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 0.01 mass% or more and 0.15 mass% or less,

the content (CO_2 conversion value) of the metal carbonate having a grain diameter of $75\text{ }\mu\text{m}$ or more ($C_{\text{CO}_2, 75\text{ }\mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 4.6 mass% or more, and

a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $150\text{ }\mu\text{m}$ or more ($C_{\text{CO}_2, 150\text{ }\mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of $150\text{ }\mu\text{m}$ or more ($C_{F, 150\text{ }\mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 2.5 mass% or more and 4.0 mass% or less.

[Claim 8]

The shielded metal arc welding method according to claim 7,

wherein, on an electrode distal end side after use of the covered electrode, a ratio of D_2 to D_1 (D_2/D_1) satisfies 0.40 or less (including the case where the ratio is 0),

wherein D_1 is a distance between a distal end portion of the core wire and the most distal end portion of the coating agent remaining around the core wire in a longitudinal direction of the electrode, and

D_2 is a distance between the most distal end portion of the coating agent remaining around the core wire and the rearmost portion of the coating agent remaining around the core wire in the longitudinal direction of the electrode.

[Claim 9]

The shielded metal arc welding method according to claim 8, wherein arc welding is performed such that the D_1 satisfies 2.2 mm or less.

[Claim 10]

The shielded metal arc welding method according to claim 8 or 9, wherein arc welding is performed such that a ratio of the D_1 to a diameter d of the core wire in the covered electrode (D_1/d) satisfies 1.3 or less.

[Claim 11]

The shielded metal arc welding method according to any one of claims 7 to 10,

wherein arc welding is performed in a welding position in which the covered electrode is perpendicular to a base metal or has a drag angle of more than 0° and 30° or less.

[Claim 12]

The covered electrode according to any one of claims 1 to 6, wherein a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $106\text{ }\mu\text{m}$ or more ($C_{\text{CO}_2, 106\text{ }\mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of $106\text{ }\mu\text{m}$ or more ($C_{\text{F}, 106\text{ }\mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 5.0 mass% or more and 9.0 mass% or less.

[Claim 13]

The covered electrode according to any one of claims 1 to 6, wherein a content of Al_2O_3 in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 0.02 mass% or more and 3.0 mass% or less.

[Claim 14]

The shielded metal arc welding method according to any one of claims 7 to 11, wherein a total of a content (CO_2 conversion value) of a metal carbonate having a grain diameter of $106\text{ }\mu\text{m}$ or more ($C_{\text{CO}_2, 106\text{ }\mu\text{m}}$) and a content (F conversion value) of a metal fluoride having a grain diameter of $106\text{ }\mu\text{m}$ or more ($C_{\text{F}, 106\text{ }\mu\text{m}}$) relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 5.0 mass% or more and 9.0 mass% or less.

[Claim 15]

The shielded metal arc welding method according to any one of claims 7 to 11, wherein a content of Al_2O_3 in the coating agent relative to the total mass of the coating agent ($C_{\text{coat, total}}$) is 0.02 mass% or more and 3.0 mass% or less.