

METALLIC FLUX-CORED WIRE FOR Ar-CO₂ MIXED GAS SHIELDED ARC WELDING

BACKGROUND

Technical Field

[0001]

The present invention relates to a metallic flux-cored wire for Ar-CO₂ mixed gas shielded arc welding (hereinafter, referred to as a metallic flux-cored wire for Ar-CO₂ welding) suitable for obtaining a weld metal providing a stable arc and an extremely small amount of spatter occurring, and having excellent slag removability, an excellent bead appearance/shape, excellent cracking resistance, proper proof stress, proper strength, and proper low-temperature toughness when short arc welding (short circuit transfer) in a low current region is performed in gas shielded arc welding of high tension steel in a class of a proof stress of 460 MPa or more.

Related Art

[0002]

In welding execution for an oceanic structure, a line pipe, or the like, vertical welding or overhead welding is required because a member cannot be rotated or inverted. When an initial layer of a welding joint is executed by single side penetration welding, stable short circuit transfer is required in welding without a backing material or a backing metal, but an arc becomes unstable easily and penetration welding is difficult in a rutile flux-cored wire. Therefore, gas shielded arc welding using a

solid wire or a metallic flux-cored wire is mainly applied.

[0003]

Above all, a metallic flux-cored wire for Ar-CO₂ welding has a smaller globule than a solid wire or a metallic flux-cored wire for CO₂ gas shielded arc welding, and therefore can make a bead shape flat and excellent without generating a large spatter. The metallic flux-cored wire for Ar-CO₂ welding has a low degree of slagging due to oxidation of an alloying agent or a deoxidizer such as Mn or Si, and therefore can reduce the amount of slag formation. Furthermore, the metallic flux-cored wire for Ar-CO₂ welding is also effective for improving low-temperature toughness of a weld metal due to a low content of oxygen in a weld metal, and therefore is widely applied.

[0004]

Various developments have been performed for the metallic flux-cored wire for Ar-CO₂ welding. For example, JP 2009-255164 A discloses a metallic flux-cored wire for Ar-CO₂ welding providing a reduced amount of slag formation by reduction of a content of a metal oxide or the like, an extremely small amount of spatter occurring, an excellent bead shape, and excellent low-temperature toughness of a weld metal due to regulation of a content of oxygen in iron powder to a low value. However, the metallic flux-cored wire for Ar-CO₂ welding described in JP 2009-255164 A is a flux-cored wire for welding soft steel or high tension steel in a class of 490 MPa, and has such a problem that a sufficient proof stress of a weld metal

cannot be obtained and low-temperature toughness is not sufficient in welding steel in a class of 460 MPa.

[0005]

JP 2000-197991 A discloses a flux-cored wire for mixed gas shielded arc welding providing a small amount of slag formation and capable of obtaining a flat bead shape in horizontal fillet welding. However, the flux-cored wire described in JP 2000-197991 A has such a problem that a sufficient proof stress of a weld metal, sufficient tensile strength thereof, or sufficient low-temperature toughness thereof cannot be obtained.

[0006]

JP 2007-144516 A discloses a metallic flux-cored wire for Ar-CO₂ welding containing a large amount of alloy powder. However, the metallic flux-cored wire for Ar-CO₂ welding described in JP 2007-144516 A contains Ti, and therefore generates a large amount of Ti oxide, resulting in occurring of a large amount of slag on a surface of a welding bead to deteriorate welding weldability disadvantageously.

SUMMARY

[0008]

Therefore, the present invention has been achieved in view of the above problems. An object thereof is to provide a metallic flux-cored wire for Ar-CO₂ mixed gas shielded arc welding providing a stable arc, an extremely small amount of spatter occurring, excellent slag removability, an excellent

bead appearance/shape, excellent cracking resistance, excellent proof stress of a weld metal, excellent strength thereof, and excellent low-temperature toughness thereof, in short arc welding in a low current region in gas shielded arc welding of high tension steel at a proof stress of 460 MPa or more used for a steel structure or the like.

[0009]

In order to solve the above problems, the present inventors made various studies for obtaining a component composition of a metallic flux-cored wire for Ar-CO₂ welding capable of securing a proof stress of 460 MPa or more of a weld metal, strength thereof, and low-temperature toughness thereof, and providing excellent cracking resistance, a stable arc, an extremely small amount of spatter occurring, and excellent welding weldability such as excellent slag removability or an excellent bead appearance/shape, in short arc welding (short circuit transfer) in a low current region in Ar-CO₂ mixed gas shielded arc welding of high tension steel at a proof stress of 460 MPa or more.

[0010]

As a result, the present inventors have found that it is effective to adjust a total content of a Na compound and a K compound in terms of Na₂O and K₂O, a total content of a fluorine compound in terms of F, and a content of iron powder in order to obtain a stable arc and reduce the amount of spatter occurring. In addition, the present inventors have found that a small content of SiO₂ makes a bead appearance/shape excellent and

adjustment of an Si content further makes the bead appearance/shape excellent. Furthermore, the present inventors have found that adjustment of an S content in a wire can improve slag removability.

[0011]

In addition, the present inventors have found that adjustment of contents of C, Si, Mn, Cu, and Ni in a wire can secure a proof stress of a weld metal and strength thereof, and can improve low-temperature toughness at the same time.

[0012]

Furthermore, the present inventors have found that further adjustment of contents of Ni and S can prevent high-temperature cracking and elimination of a seam of a steel outer skin can prevent low temperature cracking.

[0013]

That is, an abstract of the present invention is as follows.

[0014]

(1) A metallic flux-cored wire for Ar-CO₂ mixed gas shielded arc welding obtained by filling a flux into a steel outer skin, including, in terms of % by mass with respect to a total mass of the wire, as a total in the steel outer skin and the flux, 0.1 to 0.2% of C, 0.5 to 1.8% of Si, 1.3 to 3.0% of Mn, 0.05 to 0.45% of Cu, and 0.005 to 0.015% of S, and further including, in terms of % by mass with respect to the total mass of the wire, in the flux, 0.005 to 0.050% of a fluorine compound in terms of F in total, 0.01 to 0.20% of SiO₂, 0.02 to 0.15% of

a Na compound and a K compound in terms of Na_2O and K_2O in total, and 4.0 to 10.5% of iron powder, the balance being Fe in the steel outer skin, a Fe component of an iron alloy, and inevitable impurities.

[0015]

(2) The metallic flux-cored wire for Ar- CO_2 mixed gas shielded arc welding according to (1), further including 0.5 to 1.5% of Ni in terms of % by mass with respect to a total mass of the wire, as a total in the steel outer skin and the flux.

[0016]

(3) The metallic flux-cored wire for Ar- CO_2 mixed gas shielded arc welding according to (1) or (2), in which a seam in the molded steel outer skin is eliminated by welding a joint of the steel outer skin.

[0017]

According to the metallic flux-cored wire for Ar- CO_2 mixed gas shielded arc welding to which the present invention is applied, a welding efficiency and a quality of a welded part can be improved. For example, a weld metal providing a stable arc, capable of largely reducing a work for removing a slag or a spatter, having an excellent bead shape and excellent cracking resistance, capable of securing a proper proof stress and proper strength, and having excellent low-temperature toughness can be obtained in short arc welding in a low current region.

DETAILED DESCRIPTION

[0018]

Hereinafter, compositions of components of a metallic flux-cored wire for Ar-CO₂ welding according to an embodiment of the present invention, contents thereof, and a reason for limiting the contents of the components will be described. The content of each component will be represented by % by mass with respect to a total mass of the wire. The % by mass will be represented simply by %.

[0019]

(C: 0.1 to 0.2% as a total in steel outer skin and flux)

C improves a proof stress of a weld metal and strength thereof. However, when a content of C is less than 0.1%, this effect cannot be obtained, and a sufficient proof stress of a weld metal or sufficient strength thereof cannot be obtained. On the other hand, when the content of C is more than 0.2%, C remains in a weld metal excessively, and therefore a proof stress of the weld metal and strength thereof become too high, and low-temperature toughness thereof is reduced. When the content of C is more than 0.2%, an arc is unstable, and the amount of spatter occurring is increased. Therefore, the content of C is set to be from 0.1 to 0.2% as a total in the steel outer skin and the flux. C can be added from metal powder, alloy powder, or the like in the flux in addition to a component included in the steel outer skin.

[0020]

(Si: 0.5 to 1.8% as a total in steel outer skin and flux)

Si improves a proof stress of a weld metal, strength thereof, and low-temperature toughness thereof, increases

viscosity of a molten metal, and adjusts a bead shape. However, when a content of Si is less than 0.5%, a proof stress of the weld metal, strength thereof, and low-temperature toughness thereof are reduced. When the content of Si is less than 0.5%, viscosity of the molten metal is insufficient, and a bead has a protruding shape. On the other hand, when the content of Si is more than 1.8%, a proof stress of the weld metal and strength thereof become too high, and low-temperature toughness thereof is reduced. Therefore, the content of Si is set to be from 0.5 to 1.8% as a total in the steel outer skin and the flux. Si can be added from metal Si or alloy powder such as Fe-Si or Fe-Si-Mn in the flux in addition to a component included in the steel outer skin.

[0021]

(Mn: 1.3 to 3.0% as a total in steel outer skin and flux)

Mn remains in a weld metal, and thereby increases a proof stress of the weld metal, strength thereof, and low-temperature toughness thereof. Mn generates MnS in the weld metal, and increases high-temperature cracking resistance of the weld metal. However, when a content of Mn is less than 1.3%, these effects cannot be obtained, a sufficient proof stress of the weld metal, sufficient strength thereof, or sufficient low-temperature toughness thereof cannot be obtained, and high-temperature cracking resistance is reduced. On the other hand, when the content of Mn is more than 3.0%, Mn remains in the weld metal excessively, a proof stress of the weld metal and strength thereof become too high, and low-temperature

toughness thereof is reduced. Therefore, the content of Mn is set to be from 1.3 to 3.0% as a total in the steel outer skin and the flux. Mn can be added from metal Mn or alloy powder such as Fe-Mn or Fe-Si-Mn in the flux in addition to a component included in the steel outer skin.

[0022]

(Cu: 0.05 to 0.45% as a total in steel outer skin and flux)

Cu has a precipitation strengthening action, lowers a transformation temperature, makes a structure of a weld metal fine, and stabilizes low-temperature toughness. However, when a content of Cu is less than 0.05%, this effect cannot be obtained, and stable low-temperature toughness of the weld metal cannot be obtained. On the other hand, when the content of Cu is more than 0.45%, precipitation embrittlement occurs, and low-temperature toughness of the weld metal is reduced. When the content of Cu is more than 0.45%, high-temperature cracking occurs easily. Therefore, the content of Cu is set to be from 0.05 to 0.45% as a total in the steel outer skin and the flux. Cu can be added from metal Cu or alloy powder such as Fe-Si-Cu in the flux in addition to a component included in the steel outer skin and a Cu plating component formed on a surface of the steel outer skin.

[0023]

(S: 0.005 to 0.015% as a total in steel outer skin and flux)

S acts as a slag flocculant and a slag removing agent. However, when a content of S is less than 0.005%, the effects cannot be obtained, and slag removability thereof is

deteriorated. On the other hand, when the content of S is more than 0.015%, low-temperature toughness of a weld metal is reduced, and high-temperature cracking occurs easily. Therefore, the content of S is set to be from 0.005 to 0.015% as a total in the steel outer skin and the flux. S can be added from iron sulfide or the like in the flux in addition to a component included in the steel outer skin.

[0024]

(SiO₂ included in flux: 0.01 to 0.20%)

SiO₂ makes fitting at a bead toe of weld excellent and makes a bead appearance/shape excellent, but increases the amount of slag formation and increases a content of oxygen in a weld metal. Therefore, it is necessary to limit an addition amount of SiO₂. However, when a content of SiO₂ is less than 0.01%, fitting of a weld bead at a bead toe of weld is poor, and a bead appearance/shape is poor. On the other hand, when the content of SiO₂ is more than 0.20%, a content of oxygen in the weld metal is increased, and low-temperature toughness is reduced. Therefore, the content of SiO₂ in the flux is set to be from 0.01 to 0.20%. SiO₂ can be added from silica sand in the flux, a solid component of water glass formed of sodium silicate and potassium silicate, and the like.

[0025]

(Total content of fluorine compound in terms of F in flux: 0.005 to 0.050%)

A fluorine compound stabilizes an arc. However, when a total content of the fluorine compound in terms of F is less

than 0.005%, this effect cannot be obtained sufficiently, and the arc is unstable. On the other hand, when the total content of the fluorine compound in terms of F is more than 0.050%, the arc is unstable, and the amount of spatter occurring is increased. Therefore, the total content of the fluorine compound in terms of F is set to be from 0.005 to 0.050%. The fluorine compound can be added from CaF_2 , NaF , LiF , MgF_2 , K_2SiF_6 , Na_3AlF_6 , AlF_3 , or the like. The content in terms of F is a total content of F included therein.

[0026]

(Na compound and K compound in flux in terms of Na_2O and K_2O in total: 0.02 to 0.15%)

A Na compound and a K compound make an arc soft and stabilize the arc. However, when a total content of the Na compound and the K compound in terms of Na_2O and K_2O is less than 0.02%, the arc is unstable, and the amount of spatter occurring is increased. On the other hand, when the total content of the Na compound and the K compound in terms of Na_2O and K_2O is more than 0.15%, the arc is strong, and the amount of spatter occurring is increased. In addition, fitting at a bead toe of weld is poor, and a bead appearance/shape is poor. Therefore, the total content of the Na compound and the K compound in terms of Na_2O and K_2O in the flux is set to be from 0.02 to 0.15%. The Na compound and the K compound can be added from potassium feldspar in the flux, a solid component of water glass formed of sodium silicate and potassium silicate, and powder of sodium fluoride, potassium silicofluoride, or the

like.

[0027]

(Iron powder in flux: 4.0 to 10.5%)

Iron powder is added from the flux in order to secure a high welding property which is a characteristic of a metallic flux-cored wire and to adjust components. However, when a content of iron powder is less than 4.0%, the high welding property is reduced, and a bead appearance/shape is poor. In addition, when the content of iron powder is less than 4.0%, an arc is unstable, and the amount of spatter occurring is increased. On the other hand, when the content of iron powder is more than 10.5%, a flux filling ratio is varied in a wire longitudinal direction in a stretching step in manufacturing, the arc is unstable, and the amount of spatter occurring is increased. Therefore, the content of iron powder in the flux is set to be from 4.0 to 10.5%.

[0028]

The metallic flux-cored wire for Ar-CO₂ welding according to an embodiment of the present invention more preferably uses hydrogen-reduced iron powder, atomized iron powder, or the like having a content of oxygen of 0.25% or less. Use of the iron powder having a low content of oxygen makes it possible to suppress a content of oxygen in a weld metal to 0.05% or less without adding a strong deoxidizer to increase the amount of slag formation, such as Ti, Al, Mg, or Zr, and therefore makes it possible to further improve low-temperature toughness of the weld metal.

[0029]

(Ni: 0.5 to 1.5% as a total in steel outer skin and flux)

Ni secures low-temperature toughness of a weld metal, and improves hardenability of the weld metal, a proof stress thereof, and strength thereof. However, when a content of Ni is less than 0.5%, this effect cannot be obtained sufficiently, and a required proof stress of the weld metal, required strength thereof, or required low-temperature toughness thereof cannot be obtained. On the other hand, when the content of Ni is more than 1.5%, a proof stress of the weld metal and strength thereof are too high, and low-temperature toughness thereof is reduced. When the content of Ni is more than 1.5%, high-temperature cracking occurs easily. Therefore, the content of Ni in the flux is set to be from 0.5 to 1.5%. Ni can be added from metal Ni or metal powder such as Fe-Ni in the flux in addition to a component included in the steel outer skin. In a metallic flux-cored wire for Ar-CO₂ welding to which an embodiment of the present invention is applied, it is not essential to set the content of Ni to a range of 0.5 to 1.5% as a total in the steel outer skin and the flux. Even when the content of Ni is outside this range or no Ni is included, hardenability of a weld metal, a proof stress thereof, strength thereof, and low-temperature toughness thereof satisfy performance expected by an embodiment of the present invention.

[0030]

(Elimination of seam of steel outer skin)

The metallic flux-cored wire for Ar-CO₂ welding according

to an embodiment of the present invention has a structure obtained by molding a steel outer skin into a pipe-like shape and filling a flux thereinto. The kind of the wire is roughly classified into a wire having no seam in a molded steel outer skin obtained by welding a joint of the steel outer skin, and a wire having a seam in a steel outer skin without welding a joint of the steel outer skin. The wire having no seam in the steel outer skin is preferable because the wire having no seam in the steel outer skin can be subjected to a heat treatment for reducing a total content of hydrogen in the wire, a flux after manufacturing does not absorb moisture, and therefore it is possible to reduce a content of diffusion hydrogen in the weld metal and to improve low-temperature cracking resistance.

[0031]

The balance of the metallic flux-cored wire for Ar-CO₂ welding to which an embodiment of the present invention is applied is Fe in the steel outer skin, a Fe component of iron alloy powder such as a Fe-Mn alloy, a Fe-Si-Mn alloy, or an Fe-Ni alloy, and inevitable impurities. The inevitable impurities are not particularly specified, but a content of P is preferably 0.010% or less from a viewpoint of high-temperature cracking. Ti generates a Ti oxide and increases the amount of slag formation to deteriorate welding weldability. Therefore, it is preferable to add no Ti.

[0032]

A flux filling ratio is not particularly specified, but is preferably from 8 to 20% with respect to the total mass of

the wire from a viewpoint of productivity.

[0033]

The shielding gas during welding is a mixed gas of Ar-5 to 25% CO₂ for reducing a content of oxygen in a weld metal.

[Examples]

[0034]

Hereinafter, effects of an embodiment of the present invention will be described in more detail with Examples.

[0035]

First, a steel outer skin made of JIS G3141 SPCC band steel was molded into a U-shape, and was dried to remove water sufficiently therefrom. A flux was filled into the steel outer skin. Thereafter, a seamless wire obtained by welding a joint of the steel outer skin and a seamed wire obtained by crimping steel outer skins were formed into pipes and were stretched to experimentally manufacture flux-cored wires including various components and each having a wire diameter of 1.2 mm as indicated in Table 1. A flux filling ratio was from 10 to 18%.

[0036]

[Table 1]

category	wire symbol	wire component (% by mass)											seam of wire
		total in steel outer skin and flux						in flux					
		C	Si	Mn	Cu	S	Ni	SiO ₂	content in terms of F*	total content in terms of Na ₂ O and K ₂ O	iron powder**	others***	
Examples of the present invention	A1	0.18	1.00	2.74	0.44	0.007	1.33	0.01	0.016	0.08	10.0	balance	seamless
	A2	0.15	0.53	1.75	0.27	0.009	1.15	0.18	0.048	0.08	4.0	balance	seamed
	A3	0.13	1.42	2.97	0.12	0.012	0.82	0.15	0.026	0.15	10.5	balance	seamless
	A4	0.16	1.51	2.44	0.10	0.005	1.30	0.04	0.035	0.08	7.4	balance	seamless
	A5	0.14	0.73	1.33	0.30	0.010	-	0.04	0.029	0.11	5.8	balance	seamed
	A6	0.15	0.84	2.08	0.05	0.011	0.79	0.10	0.035	0.07	9.9	balance	seamless
	A7	0.16	1.77	1.52	0.41	0.012	-	0.06	0.031	0.02	8.3	balance	seamless
	A8	0.11	1.46	1.84	0.09	0.012	1.48	0.07	0.038	0.09	8.8	balance	seamed
	A9	0.15	1.03	2.71	0.41	0.009	0.53	0.07	0.005	0.06	4.3	balance	seamless
Comparative Examples	B1	0.26	0.75	2.64	0.39	0.010	0.74	0.14	0.039	0.07	9.7	balance	seamless
	B2	0.04	0.93	2.75	0.20	0.011	1.08	0.17	0.055	0.05	5.5	balance	seamless
	B3	0.18	2.02	2.16	0.22	0.008	0.73	0.17	0.028	0.11	5.6	balance	seamed
	B4	0.13	0.44	2.14	0.15	0.012	-	0.15	0.023	0.01	10.1	balance	seamless
	B5	0.13	1.42	3.08	0.33	0.007	1.22	0.03	0.021	0.19	9.6	balance	seamed
	B6	0.17	1.44	1.23	0.22	0.011	0.43	0.07	0.022	0.12	7.6	balance	seamless
	B7	0.17	0.93	1.70	0.48	0.010	0.92	0.16	0.027	0.10	5.5	balance	seamless
	B8	0.13	0.86	2.16	0.30	0.008	1.06	0.23	0.025	0.05	7.9	balance	seamless
	B9	0.15	1.19	1.84	0.28	0.010	0.77	0.18	0.053	0.04	9.0	balance	seamless
	B10	0.16	1.54	2.77	0.35	0.011	1.62	0.004	0.043	0.09	6.6	balance	seamed
	B11	0.15	1.33	2.13	0.02	0.012	1.01	0.18	0.008	0.10	11.1	balance	seamless
	B12	0.17	0.94	1.54	0.11	0.003	1.16	0.15	0.023	0.10	3.2	balance	seamless
	B13	0.15	1.57	2.02	0.19	0.018	1.14	0.12	0.002	0.06	4.8	balance	seamless
	B14	0.14	0.43	1.43	0.31	0.015	-	0.15	0.034	0.11	7.3	balance	seamless

*: One or more kinds of CaF₂, NaF, LiF, MgF₂, K₂SiF₆, Na₃AlF₆, and AlF₃ were used as a fluorine compound.

**: Atomized iron powder having a content of oxygen of 0.25% or less was used as iron powder.

***: Others are Fe in a steel outer skin, a Fe component of iron alloy powder, and inevitable impurities.

[0037]

The experimentally manufactured wires were subjected to examination of welding weldability, a welding cracking test, and a deposited metal test using a steel plate defined by JIS G 3126 SLA 365. Welding conditions for these tests are indicated in Table 2.

[0038]

[Table 2]

Test item	welding position	plate thickness (mm)	groove	current (A)	voltage (V)	welding speed (cm/min)	shielding gas
evaluation of welding weldability	horizontal fillet	12	T joint	270	29	40	Ar-20% CO ₂ 25 L/min
deposited metal test	flat	20	in conformity with JIS Z 3111	270	30	30	
y-shape welding cracking test	flat	40	in conformity with JIS Z 3158	250	27	25	

[0039]

For the evaluation of welding weldability, an arc state, the amount of spatter occurring, slag removability, and a bead appearance/shape were examined under welding conditions indicated in Table 2 using horizontal fillet welding.

[0040]

In the welding cracking test, a test body was welded under welding conditions indicated in Table 2 at a preheated temperature of 50°C in conformity with a y-shape welding cracking test method (JIS Z 3158), and presence of high-temperature cracking was examined. Thereafter, presence of low-temperature cracking of surface cracking or cross section cracking (five cross sections) was examined for the test body 72 hours after welding by penetrant testing (JIS Z 2343).

[0041]

In the deposited metal test, welding was performed in conformity with JIS Z 3111 under welding conditions indicated in Table 2. Test pieces for a tensile test (No. A0) and an impact test (V notch test piece) were collected from a center part of a deposited metal in a plate thickness direction, and were subjected to a mechanical test. In evaluation of a proof stress and tensile strength, a test piece having a 0.2% proof stress of 460 to 600 MPa and tensile strength of 570 to 680 MPa was evaluated as being excellent. In evaluation of toughness, a Charpy impact test was performed at -60°C, each test piece was subjected to a Charpy impact test repeatedly, and a test piece having an average of three absorption energies of 65 J or more was evaluated as being excellent. Results of these tests are indicated in Table 3 collectively.

[0042]

[Table 3]

category	wire symbol	evaluation of welding weldability				cracking resistance		mechanical property			total evaluation
		arc stability	slag removability	amount of spatter occurring	bead shape/appearance	presence of high-temperature cracking	y-shape welding cracking test presence of low-temperature cracking	0.2% proof stress (MPa)	tensile strength (MPa)	vE-60(J)	
Examples of the present invention	A1	excellent	excellent	less	excellent	not observed	not observed	559	657	89	○
	A2	excellent	excellent	less	excellent	not observed	not observed	483	586	122	○
	A3	excellent	excellent	less	excellent	not observed	not observed	541	639	95	○
	A4	excellent	excellent	less	excellent	not observed	not observed	556	623	103	○
	A5	excellent	excellent	less	excellent	not observed	not observed	484	583	121	○
	A6	excellent	excellent	less	excellent	not observed	not observed	492	598	115	○
	A7	excellent	excellent	less	excellent	not observed	not observed	485	591	124	○
	A8	excellent	excellent	less	excellent	not observed	not observed	487	587	119	○
	A9	excellent	excellent	less	excellent	not observed	not observed	553	631	93	○
Comparative Examples	B1	poor	excellent	much	excellent	not observed	not observed	676	726	42	×
	B2	poor	excellent	much	excellent	not observed	not observed	428	469	121	×
	B3	excellent	excellent	less	excellent	not observed	observed	658	763	52	×
	B4	poor	excellent	much	poor	not observed	not observed	434	452	48	×
	B5	poor	excellent	much	poor	not observed	observed	662	751	31	×
	B6	excellent	excellent	less	excellent	observed	not observed	432	527	63	×
	B7	excellent	excellent	less	excellent	observed	not observed	538	634	59	×
	B8	excellent	excellent	less	excellent	not observed	not observed	559	661	39	×
	B9	poor	excellent	much	excellent	not observed	not observed	542	640	102	×
	B10	excellent	excellent	less	poor	observed	observed	631	723	36	×
	B11	poor	excellent	much	excellent	not observed	not observed	483	604	37	×
	B12	poor	poor	much	poor	not observed	not observed	561	620	75	×
	B13	poor	excellent	less	excellent	observed	not observed	570	588	41	×
	B14	excellent	excellent	less	poor	not observed	not observed	413	467	46	×

[0043]

In Tables 1 and 3, wire Nos. A1 to A9 indicate Examples of the present invention, and wire Nos. B1 to B14 indicate Comparative Examples. The wire Nos. A1 to A9 as Examples of the present invention had compositions of components within a range specified in an embodiment of the present invention. Therefore, the wire Nos. A1 to A9 had excellent welding weldability, caused no high-temperature cracking or low-temperature cracking, and had an excellent proof stress of a deposited metal, excellent tensile strength thereof, and an excellent absorption energy thereof. In this way, the wire Nos. A1 to A9 obtained extremely satisfactory results. Each of the wire symbols A2, A5, and A8 had a seam in a steel outer skin, but had a proper proof stress of a weld metal and proper tensile strength thereof, and therefore caused no low-temperature cracking. Each of the wire symbols A5 and A7 included no Ni, but included other components at compositions within a range of an embodiment of the present invention. Therefore, in the wire symbols A5 and A7, hardenability of a weld metal, a proof stress thereof, strength thereof, and low-temperature toughness thereof satisfied performance expected by an embodiment of the present invention.

[0044]

The wire symbol B1 in Comparative Examples included a large amount of C, and therefore had a high proof stress of a deposited metal, high tensile strength thereof, and a low absorption energy thereof. In addition, an arc was unstable,

and the amount of spatter occurring was large.

[0045]

The wire symbol B2 included a small amount of C, and therefore had a low proof stress of a deposited metal and low tensile strength thereof. In addition, the wire symbol B2 included a large total amount of a fluorine compound in terms of F. Therefore, an arc was unstable, and the amount of spatter occurring was large.

[0046]

The wire symbol B3 included a large amount of Si, and therefore had a high proof stress of a deposited metal, high tensile strength thereof, and a low absorption energy thereof. In addition, the wire symbol B3 had a seam in a steel outer skin, and therefore caused low-temperature cracking.

[0047]

The wire symbol B4 included a small amount of Si, and therefore had a low proof stress of a deposited metal, low tensile strength thereof, a low absorption energy thereof, and poor bead appearance/shape. In addition, a total content in terms of Na_2O and K_2O was small, and therefore an arc was unstable and the amount of spatter occurring was large. Furthermore, the wire symbol B4 included no Ni for improving a proof stress of a deposited metal, tensile strength thereof, and low-temperature toughness thereof, and therefore did not exhibit these effects.

[0048]

The wire symbol B5 included a large amount of Mn, and

therefore had a high proof stress of a deposited metal, high tensile strength thereof, and a low absorption energy thereof. In addition, the wire symbol B5 included a large amount in terms of Na_2O and K_2O as a total. Therefore, an arc was unstable, the amount of spatter occurring was large, and a bead appearance/shape was poor. In addition, the wire symbol B5 had a seam in a steel outer skin, and therefore caused low-temperature cracking.

[0049]

The wire symbol B6 included a small amount of Mn, and therefore had a low proof stress of a deposited metal, low tensile strength thereof, and a low absorption energy thereof. In addition, the wire symbol B6 caused high-temperature cracking. The wire symbol B6 included Ni for improving a proof stress of a deposited metal, tensile strength thereof, and low-temperature toughness thereof, but the content thereof was small. Therefore, the wire symbol B6 did not exhibit these effects sufficiently.

[0050]

The wire symbol B7 included a large amount of Cu, therefore had a low absorption energy of a deposited metal, and caused high-temperature cracking.

[0051]

The wire symbol B8 included a large amount of SiO_2 , and therefore had a large content of oxygen in a deposited metal and a low absorption energy.

[0052]

The wire symbol B9 included a large total amount of a fluorine compound in terms of F. Therefore, an arc was unstable, and the amount of spatter occurring was large. The wire symbol B10 included a small amount of SiO₂, and therefore had a poor bead appearance/shape. In addition, the wire symbol B10 included a large amount of Ni, and therefore had a high proof stress of a deposited metal, high tensile strength thereof, and a low absorption energy thereof. In addition, the wire symbol B10 caused high-temperature cracking. In addition, the wire symbol B10 had a seam in a steel outer skin, and therefore caused low-temperature cracking.

[0053]

The wire symbol B11 included a small amount of Cu, and therefore had a low absorption energy of a deposited metal. In addition, the wire symbol B11 included a large amount of iron powder. Therefore, an arc was unstable, and the amount of spatter occurring was large.

[0054]

The wire symbol B12 included a small amount of S, and therefore had poor slag removability. In addition, the wire symbol B12 included a small amount of iron powder. Therefore, an arc was unstable, the amount of spatter occurring was large, and a bead appearance/shape was poor.

[0055]

The wire symbol B13 included a large amount of S, and therefore had a low absorption energy of a deposited metal. In addition, the wire symbol B13 caused high-temperature cracking.

Furthermore, the wire symbol B13 included a small total amount of a fluorine compound in terms of F. Therefore, an arc was unstable.

[0056]

The wire symbol B14 included a small amount of Si, and therefore had a low proof stress of a deposited metal, low tensile strength thereof, a low absorption energy thereof, and a poor bead appearance/shape. The wire symbol B14 included no Ni for improving a proof stress of the deposited metal, tensile strength thereof, and low-temperature toughness thereof, and therefore did not exhibit these effects.

What is claimed is:

1. A metallic flux-cored wire for Ar-CO₂ mixed gas shielded arc welding obtained by filling a flux into a steel outer skin, comprising:

in terms of % by mass with respect to a total mass of the wire, as a total in the steel outer skin and the flux,

0.1 to 0.2% of C;

0.5 to 1.8% of Si;

1.3 to 3.0% of Mn;

0.05 to 0.45% of Cu; and

0.005 to 0.015% of S,

and further comprising:

in terms of % by mass with respect to the total mass of the wire, in the flux,

0.005 to 0.050% of a fluorine compound in terms of F in total;

0.01 to 0.20% of SiO₂;

0.02 to 0.15% of a Na compound and a K compound in terms of Na₂O and K₂O in total; and

4.0 to 10.5% of iron powder,

the balance being Fe in the steel outer skin, a Fe component of iron alloy powder, and inevitable impurities.

2. The metallic flux-cored wire for Ar-CO₂ mixed gas shielded arc welding according to claim 1, further comprising 0.5 to 1.5% of Ni, in terms of % by mass with respect to a total mass of the wire, as a total in the steel outer skin and the flux.

3. The metallic flux-cored wire for Ar-CO₂ mixed gas shielded

arc welding according to claim 1 or 2, wherein a seam in the molded steel outer skin is eliminated by welding a joint of the steel outer skin.