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NON-COPPER-PLATED SOLID WIRE FOR CARBON DIOXIDE GAS
SHIELDED ARC WELDING

BACKGROUND OF THE INVENTION

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Field of the Invention

The present invention relates to a solid wire for carbon dioxide gas shielded arc welding which has no copper plating on the wire surface, and more particularly to a non-copper-plated solid wire for carbon dioxide gas shielded arc welding which has improved wire feeding property or feedability, resulting from controlling the roughness and micro-hardness of the wire surface.

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Description of the Related Art

Recently, with the introduction of automatic welding systems, a solid wire for carbon dioxide (CO₂) gas shielded arc welding has widely been used in the fields of, in particular, steel frames, automobiles, ship and building construction.

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As for a solid wire for such CO₂ gas shielded arc welding, it is usual to use a so-called copper-plated solid wire wherein copper is plated on the wire surface. The reason why copper is plated is to improve electric conductivity, wire feedability and corrosion resistance.

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Due to the friction between a wire and a drawing die



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occurring in a drawing process at the time of wire manufacturing, a portion of copper plating is peeled away from the wire surface, and another portion of copper plating is deposited in the form of copper dust on dents of the wire surface.

During a welding operation, the copper dust falls from the wire surface and accumulates on a welding tip due to the friction between the wire and the welding tip. As a result, the welding tip is clogged, thereby causing welding instability and generating a large amount of spatters.

In addition to the copper dust, the copper plated wire has the following problems:

(1) The copper plating layer is more soft than the wire surface and thus the copper plating is inevitably peeled off from the wire surface due to the friction between the wire and the welding tip, thereby causing welding instability.

(2) Copper has a low melting point of $1,083^{\circ}\text{C}$ and thus is liable to be vaporized at a ultra high temperature during a welding operation, thereby generating a large amount of fumes.

In spite of these disadvantages of copper plated wires, copper plating on a wire surface has been considered to be inevitable for the purpose of improving electric conductivity.

In view of the foregoing, it is necessary to develop non-copper-plated wires capable of satisfying various characteristics including advantageous characteristics of

copper-plated wires.

Meanwhile, wires without copper plating have been proposed, for example in Japanese Patent Registration No. 2682814 (arc welding wire), Japanese Patent Application Laid-Open Publication No. Hei.11-147174 (non-plating welding wire for steel) and 2000-94178 (welding wire without plating). These prior arts propose the use of at least one kind of lubricating powder such as MoS_2 , WS_2 , and C or the coating of lubricating oil on a wire surface, for the purpose of improving wire feedability.

Japanese Patent Application Laid-Open Publication No. 2000-117484 discloses a welding wire, on the wire surface, having a wavy part of ruggedness of a predetermined wavelength along the circumferential direction, which is excellent in an arc starting property, resulting from controlling peak intensity measured in the power spectrum to a desired value. Japanese Patent Application Laid-Open Publication No. 2000-317679 discloses a non-plating wire for arc welding and an arc welding method, in which an insulating inorganic powder having a small average grain diameter and an electrically conductive inorganic powder are stuck on the welding wire surface in predetermined amounts using water soluble macromolecule, thereby generating a reduced amount of fumes or spatters.

In addition, Japanese Patent Application Laid-Open Publication No. Hei.11-342494 discloses a solid wire for carbon

dioxide gas arc welding, in which wire components, C, Si and Mn involved in spatter generation satisfy the following relationship: $(10C+2Si+Mn)=2.4$ to 5.25 wt %, thereby generating a reduced amount of spatters.

5 The above wires have improvements as non-copper-plated wires but do not satisfy all characteristics desired as welding wires. In particular, in the case of coating fine powders on the wire surface in order to improve the properties of non-copper-plated wires, the powders coated on the wire surface
10 inevitably causes the generation of fumes. Furthermore, because it is difficult to control the amount of the powders to be coated to an appropriate level, the powders are not uniformly coated on the wire surface, thereby generating an increased amount of spatters.

15 Meanwhile, in automatic welding, feedability of a welding wire is defined as the length of the wire emerging from the front end of a welding tip relative to that of the wire fed by the rotation of a feeding roller. Poor feedability may increase the length of arc and fluctuate a welding current in welding
20 operation, thereby generating an increased amount of spatters.

 In this regard, the amount of generated spatters may be used as a standard reflecting feedability of the welding wire.

25 SUMMARY OF THE INVENTION

Therefore, the present invention has been made in view of the above problems, and it is an object of the present invention to provide a non-copper-plated solid wire for CO₂ gas shielded arc welding exhibiting improved feedability, resulting from reducing the amounts of fumes and spatters due to the absence of copper plating.

In accordance with the present invention, the above object and other objects can be accomplished by the provision of a non-copper-plated solid wire for CO₂ gas shielded arc welding, in which the ten point average roughness (Rz) of the wire surface is 0.10 to 9.00 μm and the Vickers micro-hardness of the wire surface (Hv(1g)) is 125 to 310.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and other advantages of the present invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawing, in which:

Fig. 1 is a graph showing the relationship between the Vickers micro-hardness and the amount of generated spatters according to the ten point average roughness.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present inventors have tried to develop a non-copper-plated wire exhibiting superior feedability to a copper-plated wire in the absence of copper plating or applying powders as surface treating agents to the surface of the wire. As a result, they have found that the amount of generated spatters can be controlled by the adjustment of the Vickers micro-hardness and the ten point average roughness (Rz) of the wire surface, paying attention to the fact that the feedability quality of the wire depends on the amount of generated spatters in a welding operation.

In detail, where a non-copper plated solid wire for CO₂ gas shielded arc welding exhibits the ten point average roughness (Rz) of 0.10 to 9.00 μ m and the Vickers micro-hardness (Hv(1g)) of 125 to 310, the amount of generated spatters is noticeably reduced, thereby exhibiting a good feedability.

In the Vickers micro-hardness test, as already known, a diamond indenter, in the form of a pyramid with an angle of 136° between the opposite faces at the vertex, is pressed into the surface of the test piece using a prescribed force and, after the pressing force has been removed, the diagonal length of the indentation is measured. The term "Vickers micro-hardness (Hv)" as used herein is intended to mean the hardness represented as the pressing force divided by the surface area of the indentation, as the following equation:

$$H_v = \frac{2P}{d^2} \sin \frac{a}{2} = 1.854 \frac{P}{d^2}$$

wherein, P is the pressing force (kg) and d is the diagonal length of the indentation (mm).

Hv(1g) as used herein is intended to mean the Vickers
5 micro-hardness measured using the pressing force of 1g.

With respect to the ten point average roughness (Rz), in the profile curve showing wire surface roughness profile, the third highest peak and the third lowest valley of the profile on the basis of a centerline are selected within the wire
10 length. The ten point average roughness (Rz) is defined, in microns, as the vertical distance between the third highest peak and third lowest valley of the profile.

Described hereinafter is the adjustment of the ten point
15 average roughness and Vickers micro-hardness of the wire surface.

The manufacturing process of the wire is summarized as follows: starting wires (ROD) preparing, pickling, shot blasting, coating, dry drawing, degreasing, wet drawing and
20 coiling. The ten point average roughness and Vickers micro-hardness of the wire surface can be controlled to the desired range of the present invention throughout the above processes.

Hereinafter, the respective processes will be described in detail in view of the adjustment of the ten point average roughness and Vickers micro-hardness of the wire surface.

In order to increase the ten point average roughness of the final welding wires, starting wires are electrolytic pickled with sulfuric acid (in-line) to remove oxide scales on the surfaces of the starting wires. At the same time, the surfaces of the starting wires may be etched by varying an applied current density, to thereby roughen the wire surfaces.

The pickled wires may be subjected to coating or shot blasting. The shot blasting sharply increases the roughness of the wire surfaces.

The coating, dry drawing and degreasing processes are conventional processes for wire manufacturing and have nothing to do with the characteristics of the present invention.

The Vickers micro-hardness of wire surfaces is mainly controlled by the wet drawing process as will be described hereinafter.

The Vickers micro-hardness of the wire surfaces generally increases as the tensile strength of the wires is higher. However, the increased tensile strength alone cannot increase the micro-hardness of the subsurface area ranging from several μm to several tens μm from the wire surfaces.

In this regard, area reduction in drawing dies can be considered. If the reduction angle (2α) of final drawing dies

in the wet drawing process increases to a range of 8 to 40 degrees, the micro-hardness of the subsurface area ranging from several μm to several tens μm from the wire surfaces can be increased.

5 Larger drawing force in the drawing process may generate the die marks on the wires. In order to prevent this phenomenon, it is necessary to lower respective workabilities of the dies to 5 to 12% by adjustment of the number of the drawing.

10 In detail, in order to lower the workability of each die to 5 to 12%, if the reduction angles of final dies (2α) are 8 degrees, the number of the drawing is controlled to be 1 to 4 times, and if they are more than 8 degrees, the number of the drawing is controlled to be 2 to 5 times.

15 By way of example, in case of the dies with the reduction angle (2α) of 40 degrees, weak wet drawing processes of 2 to 5 times may prevent the occurrences of the die marks. At the same time, because the surface layers of the wires are mainly work hardened, hardness of the wire surface layers provided by the
20 drawing process is added to the Vickers micro-hardness, which is proportional to the total workabilities of the wires. As a result, the Vickers micro-hardness of the wire surfaces preferably increases, whereby the surface hardness (H_v) of 300 or more is accomplished.

On the other hand, wires with the Vickers micro-hardness (Hv) as low as 100 can be obtained by carrying out the following processes in order: dry drawing, annealing, pickling and wet drawing.

5 The Vickers micro-hardness is also related to the tensile strength of the wires. Therefore, it is understood that the surface hardness may be controlled by varying the diameters of starting wires (ROD).

10 Examples

Hereinafter, the effectiveness of the present invention will be described by way of inventive examples and non-limiting comparative examples.

15 Respective starting wires (ROD) comprising, as chemical components for the wires, 0.06 wt% of C, 0.9 wt% of Si, 1.4 wt% of Mn, 0.014 wt% of P, 0.009 wt% of S, and 0.11 wt% of Ti, and having wire diameter sizes of 8 mm, 6.4 mm and 5.5 mm, were prepared. These wires were electrolytic pickled in 15% H₂SO₄ solution at 45°C.

20 Some of the pickled wires were subjected to shot blasting others were not short blasted. The surface roughness of the wires was varied by different shot velocity such as slow, medium and fast in the shot blasting operation.

25 Then, the wires were coated with conventional phosphate (Bonderite) films and then with 15% Borax, followed by drying

and coiling. Processes from the pickling to the coating were in-line processes.

Subsequently, the wires were subjected to dry drawing under conventional conditions to thereby obtain dry drawn wires with medium diameter sizes of 1.3 mm to 2.5 mm. The dry drawing was repeated 12 to 16 times at a rate of 600 m/min. The dry drawing dies were tungsten carbide dies.

The dry drawn wires were alkaline electrocleaned. Before the alkaline electrocleaning, lubricants of the surfaces of the wires were physically removed with steel wool.

In order to prepare some wires that had the low Vickers micro-hardness, the dry drawing was followed by intermediate annealing at 880°C and electrolytic pickling.

In the final wet drawing, dies having reduction angles of 8, 12, 18, 25, 30, 35 and 40 degrees were used to control the Vickers micro-hardness of each wire. The final welding wires were 1.2 mm in diameter.

As the reduction angle (2α) increases, area reduction percentages (workability) of the wet drawing dies decrease, as shown in Table 1. Therefore, the surface layers of the wires were mainly work-hardened and drawing forces were lowered, thereby preventing the generation of die marks.

Table 1

Reduction angle (2α)	Area reduction (%)
8	18
12	16
18	12
25	8
30	5
35	5
40	5

By way of combining the process conditions as described above, various wires each having different surface roughness and Vickers micro-hardness were prepared. Each wire was welded under the welding conditions indicated in Table 2 and then the amount of generated spatters was determined.

Table 2

Diameter of wire	Welding Voltage	Welding current	Welding speed	Shield gas	Welding position
1.2 mm	22 V	160 Amp	20 cm/min	CO ₂ 100% (20 l /min)	Downward position

Steel plates each having a thickness of 12 mm, a width of 10 cm and a length of 50 cm were placed in boxes measuring 80cm x 15 cm x 20 cm. A 40 cm length of bead-on-plate welding was carried out for 2 minutes and then generated spatters were collected to thereby determine weight per unit time (mg/min).

The ten point average roughness (Rz) of each wire surface was calculated by averaging four roughness measurements taken around a circumference of the wire.

Similar to the measurement of the ten point average roughness, the Vickers micro-hardness (Hv) of the wire surfaces that were visualized under a microscope was calculated by averaging a total of 16 hardness measurements, that is, 4 measurements from each of 4 circumferences of the wire. The pressing force used was 1g.

The amount of spatters generated depending on the Vickers micro-hardness (Hv) at various ten point average roughness (Rz) is presented in Table 3.

Table 3

Example	Rz (μm)	Hv (1g)	Amount of spatters (mg/min)	Amount of fumes (mg/min)	Remark
1	0.08	90	810	0	Comparative examples
2		123	630	0	
3		150	560	0	
4		250	505	0	
5		300	570	0	
6		350	650	0	
7	0.10	95	610	0	Inventive examples
8		122	405	0	
9		125	400	0	
10		130	394	0	
11		175	330	0	
12		250	325	0	
13		306	389	0	
14		310	400	0	
15		315	407	0	Comparative examples
16		350	625	0	
17		378	718	0	
18	0.39	100	480	0	
19		122	406	0	

Table 3 (continued)

Example	Rz (μm)	Hv (1g)	Amount of spatters (mg/min)	Amount of fumes (mg/min)	Remark
20	0.39	125	398	0	Inventive examples
21		130	390	0	
22		185	280	0	
23		280	300	0	
24		306	390	0	
25		310	400	0	
26		316	406	0	Comparative examples
27	1.98	377	625	0	
28		75	475	0	
29		100	450	0	Inventive examples
30		122	404	0	
31		125	400	0	
32		127	395	0	
33		200	210	0	
34		290	311	0	
35		306	390	0	Comparative examples
36	8.05	315	408	0	
37		360	470	0	
38	8.05	100	428	0	

Table 3 (continued)

Example	Rz (μm)	Hv (1g)	Amount of spatters (mg/min)	Amount of fumes (mg/min)	Remark
39	8.05	122	405	0	Comparative example
40		127	397	0	Inventive examples
41		166	180	0	
42		250	168	0	
43		300	289	0	
44		307	392	0	
45		310	399	0	
46		316	406	0	Comparative examples
47		360	450	0	
48		100	750	0	
49	9.00	110	560	0	Inventive examples
50		123	408	0	
51		125	400	0	
52		130	390	0	
53		175	355	0	
54		250	357	0	
55		300	389	0	
56		308	393	0	
57		310	400	0	

Table 3 (continued)

Example	Rz (μm)	Hv (1g)	Amount of spatters (mg/min)	Amount of fumes (mg/min)	Remark
58	9.00	318	408	0	Comparative examples
59		350	580	0	
60	9.10	95	688	0	
61		121	580	0	
62		126	518	0	
63		150	455	0	
64		260	448	0	
65		308	470	0	
66		322	510	0	
67		368	625	0	
68	13.00	116	740	0	
69		120	670	0	
70		127	625	0	
71		150	590	0	
72		250	575	0	
73		300	585	0	
74		310	590	0	
75		340	670	0	
76		375	750	0	

Table 3 (continued)

Example	Rz (μm)	Hv (lg)	Amount of spatters (mg/min)	Amount of fumes (mg/min)	Remark
77	14.90	110	800	0	Comparative examples
78		121	760	0	
79		125	750	0	
80		150	692	0	
81		225	703	0	
82		300	685	0	
83		310	678	0	
84		350	730	0	

As shown in Table 4 below, in which the amount of
 5 generated spatters and the wire feedability are listed, the
 maximum amount of generated spatters giving acceptable
 feedability is 400 mg/min.

Table 4

Amount of spatters (mg/min)	Feedability
0 - 250	Excellent
250 - 400	Good
400 - 700	Normal
700 - 850	Somewhat poor
850 or more	Poor

Fig. 1 is a graph illustrating the data of Table 3. It can be seen from Fig. 1 that only in case of wires having the ten point average roughness (Rz) of 0.10 to 9.00 μm and the Vickers micro-hardness (Hv(1g)) of 125 to 310, the amount of generated spatters is 400 mg/min or less, thereby guaranteeing good feedability.

Welding wires are in firm contact with the inside of a feeding cable and the inside of a welding tip while being fed by a feeding roller. Therefore, it can be said that the roughness and/or hardness of the wire surface is intimately connected with the wire feedability. In detail, wire feedability is excellent only in specified surface roughness and hardness value ranges.

In particular, according to the present invention, wire feedability is closely related to the micro-hardness of the outermost surface layer of the wire measured under a micro

pressing force, not to the total surface hardness of the wire that is proportional to the tensile strength of the wire.

Meanwhile, when a conventional copper-plated solid wire, JIS Z3312 YGW12 with 1.2 mm diameter was welded under a welding current of 250A, 5 to 6 mg of Cu fumes were generated. The Japanese Society of Occupational and Environmental Hygiene has not recommended a permissible concentration of copper fumes. However, according to papers presented at the meeting of the American Society of Occupational and Environmental Hygiene, the permissible concentration of copper fumes is 0.2 mg/m³.

In an actual welding operation, the generation of excess Cu fumes can be avoided by wearing an appropriate protective mask and using a suitable suction equipment. However, it can be understood that because non-copper-plated wires for welding are used in the present invention, it is not necessary to consider the generation of Cu fumes.

As apparent from the above description, the present invention provides a non-copper-plated solid wire for CO₂ gas shielded arc welding with excellent feedability, which generates a reduced amount of spatters when welded at a relatively low current area, resulting from controlling the ten point average roughness (Rz) of the wire surface to 0.10 to 9.00 μm and the Vickers micro-hardness of the wire surface (Hv(1g)) to 125 to 310. Therefore, the welding operation can

be carried out with high efficiency to produce a weld of good quality.

Although the preferred embodiments of the present invention have been disclosed for illustrative purposes, those
5 skilled in the art will appreciate that various modifications, additions and substitutions are possible, without departing from the scope and spirit of the invention as disclosed in the accompanying claims.

WHAT IS CLAIMED IS:

1. A non-copper-plated solid wire for CO₂ gas shielded arc welding, in which the ten point average roughness (Rz) of the wire surface is 0.10 to 9.00 μm and the Vickers micro-hardness of the wire surface (Hv(1g)) is 125 to 310.