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LOW-FUME WIRE FOR GAS SHIELDED ARC WELDING

This invention relates to a low fume wire for gas shielded arc welding.

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The demand for gas shielded arc welding wires has been increasing in step with the development of automatic and semi-automatic welding techniques.

10 However, as compared with covered electrodes, the gas shielded arc welding wires generate a large amount of fumes which are hazardous to the health of the machine operators. In this regard, Japanese Regulations for the Prevention of Dust Affliction (Ordinance No. 18 of the Japanese Ministry of Labor, 15 1979) were put into effect to comply with an increasing social demand for the improvement of welding environments. In addition, there has been another problem in that observation of the welding line is hindered by the fumes when performing the 20 welding operation in a poorly ventilated place, resulting in a low accuracy of the operation.

In order to eliminate the adverse effects of fumes, it is conceivable (1) to lower the fume concentration 25 by ventilation, (2) to remove the fume through a duct which is located in the vicinity of the welding point, (3) to put on a dust respirator or (4) to reduce the amount of the fume by improving the welding material or method. With regard to the countermeasures 30 (1) to (3), there have been proposed various methods and apparatus, which however are all ex post facto

solutions, without aiming to reduce the production of the fumes as in the countermeasure (4). Nevertheless, there have thus far been made a small number of proposals in respect of countermeasure (4), including
5 Japanese Patent Publication no. 53-1216 (relating to a low fume composite wire for non-gas shielded welding).

It has been confirmed by experiments that the fume generation which is influenced by the welding condition
10 can be reduced by lowering the welding current and voltage or alternatively by increasing the Ar content of the shielding gas. However, reducing the welding current and voltage leads to impairment of the high operational efficiency which is characteristic of the
15 gas shielded arc welding and degrades the bead shape, while an increase of the Ar content gives rise to an increased cost.

Consequently, in order to reduce the problem of fume
20 production while retaining the characteristic advantages of the gas shielded arc welding and in addition to comply with the requirements of economy and bead shape, it is necessary to improve the composition of the wire itself besides restrictions of the welding condition.

25 According to the present invention, there is provided a low fume wire for gas shielded arc welding comprising, as constituents, C present but less than or equal to 0.06%, 1.65 to 1.95% of Mn, 0.8 to 1.0% of Si, S present
30 but less than or equal to 0.015%, a deposited carbon coating on the surface of the wire comprising 0.02% or less and a copper coating on the surface of the wire

comprising less than 0.25%, all of the percentages being percentages of the total weight of said wire and coatings, the balance comprising iron and inevitable impurities.

- 5 Wire of such composition reduces fume generation particularly when it is used in short circuit transfer welding which is performed in a relatively low current range.
- 10 The present invention also provides a low fume wire for gas shielded arc welding comprising, as constituents, C present but less than or equal to 0.06%, 1.65 to 1.95% of Mn, 0.8 to 1.0% of Si, S present but less than or equal to 0.015%, 0.005 to 0.25% of Al, 0.01 to 0.25% of
- 15 Ti, a deposited carbon coating on the surface of the wire comprising 0.02% or less and a copper coating on the surface of the wire comprising less than 0.25%, all of the percentages being percentages of the total weight of said wire and coatings, the balance comprising
- 20 iron and inevitable impurities.

In the accompanying drawings:

- Figure 1 is a partly cut away perspective view of apparatus for measuring the quantity of fumes generated;
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Figure 2 to Figure 6 are diagrams graphically showing the amount of fumes generated in relation to the contents of C, Mn, Si P and S of the wire respectively;

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Figures 7 and 8 are diagrams showing the amount of fumes generated in relation to the amount of C forming a surface deposit and the amount of Cu plating on the wire, respectively;

Figures 9 and 10 are diagrams showing the amount of fumes generated in relation to the Ti and Al contents of the wire, respectively; and,

5 FIGURES 11 and 12 are photographs of the short-circuit transfer welding process.

10 With regard to the welding wire for short circuit welding, there have been used steel wires which contain less than 0.15% of C, 0.50 to 1.20% of Si and 0.90 to 1.90% of Mn which ensure their workability, welding ability and performance quality. Therefore, experiments were conducted to study the fume generation in relation with the contents of
15 these wire components and other elements which are inevitably present in or on the wires, paying special attention to the wire components C, Mn, Si, P and S. The conditions of the experiments were as follows.

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Basic wire composition: 0.08%C, 1.56%Mn,
0.92%Si, 0.015%P,
0.010%S

Wire diameter: 1.2 mm ϕ

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Components of surface deposits (explained later) :

0.03% of C deriving from surface deposits;
0.20% of plated Cu

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Test strips:

Mild steel (JIS G 3106),
12 mm thick

Welding conditions:

150A x 21V x 30cm/min

Shielding gas:

CO₂, 20l/min

Fume measuring method:

5 All of the fumes generated during
each welding experiment was collected
by a high volume sampler according
to JIS 3930, using the measuring
10 apparatus of FIG. 1 including a
collecting box 1, a sampler 2, a
peep window 3, a hand inserting hole 4,
air holes 5 (40 mm ϕ), a welding table
6, and test strips 7. The same
experiment was repeated three times to
evaluate the results to give a mean
value of the fume generation per
unit time (mg/min).

15 The results of the experiments are shown in
FIGURES 2 to 6.

As is clear from FIGURES 2 to 6, the amount of fumes
generated becomes smaller with a reduction of C and S
20 contents and an increase of Mn and Si contents, and is
not influenced by the P content. This is considered
to be attributable to the following reasons. The
fumes are generated by condensation of oxidized vapours
of the solvent component which is released into the
25 air upon evaporation by the high arc heat. In the
short circuit transfer welding, the hot vapours in
the arcing atmosphere are released into the air at
the time of re-arcing (Photograph 2) after the short-
circuit period (Photograph 1), thereby generating
30 fume. Therefore, presumably the tendency that the

number of short-circuits which encourage the generation of fumes is reduced by reductions in the C and S contents S and increases in the Mn and Si contents is reflected by the amount of fume generation. The contents of the above-mentioned wire components are restricted to particular ranges based on these observations and the following reasons.

C: present but less than or equal to 0.06%

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The element C has the effect of strengthening the arc by increasing its concentration but the generation of fumes is increased conspicuously in proportion to the C content as seen FIGURE 2. Besides, it lowers the toughness and cracking resistance of the deposited metal, coupled with a deterioration in wire drawability in the wire forming stage. Judging from overall considerations, then, C should be present but less than or equal to 0.06%.

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Mn: 1.65 to 1.95%

This component serves to enhance the performance quality of the wire by stabilizing the arc and to reduce the amount of generation of fumes. Therefore, it should be more than 1.65% but should be restricted to 1.95% since excessive Mn contents will increase the cost of raw material and harden the wire, lowering the wire drawability.

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Si: 0.8 to 1.0%

Si which acts as a deoxidizer enhances the anti-porosity of the deposited metal. As is clear from
5 FIGURE 4, it should be more than 0.8% for suppressing the generation of fumes. The Si content, however, should be limited to 1.0% since otherwise it will lower the toughness of the deposited metal.

10 S: present but less than or equal to 0.015%

The component S barely adversely affects the performance quality of the wire but it slightly increases the amount of fume generation as is clear
15 from FIGURE 6. If present in excess, it tends to lower the toughness and anti-porosity of the deposited metal, so that S should be present but less than or equal to 0.015%.

Apart from the foregoing components, the elements
20 Al and Ti which reduce the number of short-circuits have a favourable influence on the reduction of fumes. However, in the case of short-circuits transfer welding, it is recommended not to positively include them in view of deterioration in performance
25 quality which would occur in the short circuit transfer region.

Although fume generation can be suppressed to a considerable degree by restricting the minor
30 components of the wire to the above-defined ranges, for example, by 10 to 20% as compared with

conventional wires, this is not sufficient for realizing a drastic reduction of fume generation as contemplated by the present invention. A fume reduction of 30% or greater is preferred and will make a useful difference to practical welding operations. Therefore, our study was extended to other conditions of the wire, and as a result it was confirmed that fume generation was closely related to the C content of the impurities (mainly deriving from lubricant) deposited on the wire surface in the wire drawing stage, and with the amount of Cu which is plated on the wire to prevent oxidation or to improve the wire feed or electric conduction.

The following experiments were conducted to study the influences of the secondary, surface, C content and Cu plating.

Influence of Deposited C

The influence on fume generation of the amount of (secondary) C derived from the surface deposits was examined by varying the secondary C content of sample wires (1.2 mm ϕ) containing 0.05% of C, 1.60% of Mn, 0.90% of Si, 0.015% of P and 0.010% of S, and coated with 0.20% of Cu plating. The welding conditions and the method of measuring the quantity of generated fume were the same as in FIGURES 2 to 6. The results are shown in FIGURE 7.

Influence of Cu Plating

The influence on fume generation of the Cu plating was examined by varying the amount of Cu plating on sample wires (1.2 mm ϕ) containing 0.08% of C, 1.56% of Mn, 0.92% of Si, 0.015% of P and 0.010% of S, and bearing a secondary (deposited) C amount constantly at 0.03%. The welding condition and the method of measuring the quantity of fumes generated were the same as in the foregoing experiment. The results are shown in FIGURE 8.

As is clear from FIGURES 7 and 8, the generation of fumes diminishes with reductions in the amount of C deriving from the surface deposits and in the amount of Cu plating, reflecting the reduction of the number of short-circuits as mentioned hereinbefore. In addition, the reduction in the content of C which blows off hot gases from the arc by explosions after oxidation into CO₂ or CO gas in the arc atmosphere is considered to have had a favourable effect on the reduction of fume generation. It is assumed that this effect is further enhanced by the reduction of the amount of plated Cu which has a high vapour pressure and therefore may cause higher fume generation by increasing the hot gases in the arc atmosphere.

The C content of the surface deposits and the amount of Cu plating on the conventional gas shielded arc welding wires are generally about 0.05% and 0.30%,

respectively, and it has been the general practice to produce such wires without strict control of the composition in terms of fume generation in the absence of suitable teachings in this regard.

- 5 However, as clear from the experimental results of FIGURES 7 and 8, the fume generation can be further reduced by restricting the C content of the surface deposits to less than 0.02% and the amount of Cu plating to less than 0.25%

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Control of the deposited C content and the amount of Cu plating in addition to the control of the contents of the afore-mentioned wire components produces an enhanced or synergistic effect on the

- 15 suppression of fume generation, reducing the generation of fumes of the wire as a whole by more than 30% as compared with conventional counterparts as will be shown by experimental examples hereinafter.

- 20 With regard to the wire for use in globular transfer welding which is performed in a relatively large current range, the relationship of fume generation to the wire contents C, Mn, Si, P and S, the content of C present as a surface deposit, and the
- 25 amount of Cu plating were studied in the same manner as in the case of the foregoing short circuit transfer welding. As a result, a conclusion was reached that, for the suppression of fume generation, the respective components should be restricted to
- 30 the same ranges as in the short circuit transfer welding wire although the globular transfer welding

involved slightly different fume reducing mechanisms. More particularly, the components C and S which have a high ionization potential tend to activate the arc column when thrown into the arc, thereby enhancing the arc energy (arc temperature). Therefore, they increase the quantity of hot vapours in the arc, a source of fumes, and thus they lend themselves to an increase of fumes. It follows that fume generation can be suppressed by reducing the C and S contents of the wire. On the other hand, the Mn and Si contents which have a low ionization potential show an inverse trend so that, with a view to suppressing fume generation, they should be present in predetermined amounts. However, if Mn and Si are present in excess of the respective upper limits defined hereinbefore there will arise the same problems as in the case of the short circuit transfer welding wire. Further, the C content of the surface deposits and the amount of Cu plating also have the same effects as in the case of the short circuit transfer welding wire and therefore should be limited to the above-defined ranges for the same reasons.

Apart from the foregoing components, the wire for the globular transfer welding includes Ti, Al or the like for forming transfer droplets into globules or for improving the welding performance. According to preliminary experiments, the Ti and Al contents exhibit a close relationship to fume

generation. Therefore, the quantitative relationships of the Ti and Al contents with the amount of fume generated were studied by further experiments, measuring the quantities of fume generated in the welding experiments using sample wires with different Ti and Al contents under the following conditions.

Sample Wires

Wires of 1.2 mm ϕ , containing 0.08% of C, 1.56% of Mn, 0.92% of Si, 0.015% of P and 0.01% of S along with 0. to 0.32% of Ti and Al, 0.03% of C derived from surface deposits (based on the total weight of wire), and 0.20% of plated Cu (do).

Welding Conditions

Welding current:	300A, DC (wire+)
Welding voltage:	35V
Welding speed:	30 cm/min
Shielding gas:	CO ₂ , 20 l/ min
Sample steel strips:	Mild steel (JIS G 3106), 12 mm thick

The results are shown in FIGURES 9 and 10

As is clear from Figures 9 and 10, fume generation is reduced considerably by increases in the Ti content of the wire, and this effect is produced effectively when the Ti content is greater than 0.01%. Besides, Ti has the effect of smoothing the transfer of molten droplets at large welding currents particularly

when its content is in excess of 0.01%.

However, the Ti content should be limited to 0.25% since otherwise it will lower the toughness of the deposited metal. On the other hand, as is clear from FIGURE 10, fume generation is reduced markedly by increases in the Al content of the wire in a certain range. Further, the Al component acts as a deoxidizer to enhance the resistance to blow holes when its content is greater than 0.005%. However, the upper limit should be 0.25% as excessive Al contents tend to increase fume generation.

Thus, in the case of a wire for globular transfer welding, it is also possible to reduce the generation of fumes to about 30% of that using conventional wires by strictly controlling the Ti and Al contents of the wire in addition to the contents of C, Mn, Si and S, along with the restriction of the C content of the surface deposit and the amount of Cu plating to the predetermined ranges based on the total weight of the wire.

In order to reduce the C content of the surface deposit, mainly originating from the lubricant which is applied in the wire drawing stage, it is possible (1) to reduce the C content of the lubricant itself or (2) to reduce the amount of the residual lubricant (more specifically to increase the speed of the core wire in the lubricant applying stage, to reduce the amount of the lubricant in the lubricant applying medium or to remove the residual lubricant by baking, washing with solvent, brushing or other means). Further, in the case where a C-containing

arc stabilizer is applied to the wire, the amount of C can be restricted by employing a stabilizer with a smaller C content or by reducing the amount deposited.

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A simple and effective method for reducing the amount of Cu plating is to lower the electrolytic current or to increase the speed of wire travel through the electroplating bath.

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Thus, the present invention has succeeded in reducing the generation of fumes to a significant degree by determining the kinds and contents of the wire components in both the short circuit

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transfer welding and globular transfer welding processes, coupled with the restrictions of the C content of the surface deposits and the amount of Cu plating. The wire of the invention has great practical advantages such as the improvement of the working environment and lessening the burden for the fume removing apparatus.

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The invention is illustrated more particularly by the following examples.

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Example 1

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There were prepared gas shield arc welding wires with the compositions, the C contents of surface deposits, and the amounts of Cu plating as shown in Table 1 (short circuit transfer welding wires with Ti and Al contents less than 0.01%). The

fume generation of the respective wires were examined by welding tests (a bead-on-plate method) under the following conditions. The quantity of fume generated was measured by the use of the measuring apparatus of FIGURE 1.

Testing Conditions

10	Welding current:	150A, DC (wire+)
	Welding voltage:	21V
	Welding speed:	30 cm/min
	Shielding gas:	CO ₂ , 20 l/min
	Base metal:	Mild steel (JIS G 3106)
15		12 mm thick, 0.12%C, 0.29%Si, 1.44%Mn, 0.020%P, 0.008%S
	Tip extension:	17 mm

The results are shown in Table 1.

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Table 1

Wire No.	Chemical Composition (wt%)				Deposited C (wt%)	Cu plating (wt%)	Fume (mg/min)	Rating*	Remarks
	C	Mn	Si	S					
1	0.10	1.40	0.85	0.025	0.05	0.20	270	x	Conventional
2	0.04	1.70	0.90	0.015	0.02	"	188	○	Invention
3	0.09	1.60	0.90	0.010	0.018	"	218	Δ	Comparative example
4	0.04	1.40	"	"	"	"	208	○	"
5	"	1.60	"	0.020	"	"	198	○	"
6	"	"	"	0.010	0.030	"	228	Δ	"
7	"	"	"	"	0.018	0.27	203	○	"
8	"	"	"	"	0.030	0.30	245	x	"
9	0.02	1.80	0.95	"	0.010	0.15	172	○	Invention
10	0.03	1.75	0.90	0.015	"	0.005	165	○	"
11	0.05	1.65	0.85	"	0.005	0.12	187	○	"

*Rating: The symbols "x", "○", "Δ" and "Δ" represent reductions of fume generation of 0 - 10%, 10 - 20%, 20 - 30% and more than 30% based on the quantity of fume in the conventional wire (No. 1).

Following are observations on the test results of Table 1.

- 5 (1) Wire No. 1 which deviated from the predetermined range in the contents of the wire components C, Mn and S and in the C content of the surface deposits generated an extremely large amount of fumes.
- 10 (2) Wire Nos. 3 to 5 which deviated from the predetermined range in the content of one of the wire components were insufficient in fume suppressing effect.
- 15 (3) Wire Nos. 6 to 8 which contained the wire components in the predetermined ranges except for either the C content of surface deposits or the amount of Cu plating were unable to suppress fume generation to a sufficient degree.
- 20 (4) In contrast, Wire Nos. 2 and 9 to 11 which satisfied the conditions of the present invention could reduce fume generation by more than 30% as compared with Wire No 1.

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Example 2

There were prepared gas shielded arc welding wires (for globular transfer welding) with the compositions, C contents of surface deposits, and amounts of Cu plating as shown in Table 2, followed by welding

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tests under the same conditions as in Example 1 except that the welding current and voltage were set at higher levels of 300A and 35V, respectively, for ensuring globular transfer.

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The test results are shown in Table 2.

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Table 2

Wire No.	Chemical Compositions (wt%)						Deposited C (wt%)	Cu plating (wt%)	Fume (mg/min)	Rating*	Remarks
	C	Mn	Si	S	Ti	Al					
1	0.08	1.55	0.80	0.015	0.15	0.03	0.06	0.20	604	x	Conventional
2	0.02	1.65	0.90	"	0.17	0.01	0.02	"	414	⊙	Invention
3	0.03	1.70	0.85	"	"	"	0.05	0.26	547	x	Comparative example
4	0.04	1.70	0.90	0.010	0.005	0.005	0.02	0.18	474	⊙	"
5	0.05	1.75	0.85	0.015	0.15	0.01	"	0.13	421	⊙	Invention

*Rating: Same as in Table 1.

According to the test results of Table 2, the respective wires were assessed as follows.

(1) Wire No. 1 (conventional) which deviated
5 from the predetermined range in the wire contents C and Mn and the C content of the surface deposit generated an extremely large quantity of fumes.

(2) Wire No. 3 which satisfied the conditions
10 of the invention except for excessive amounts of deposit Cu plating showed no distinctive reduction in fume generation, while Wire No. 4 of a comparative example with a deviation only in the Ti content was insufficient in the fume suppressing
15 effect.

(3) Wire Nos. 2 and 5, examples according to
the present invention, is reduced in the amount
of fume generation by more than 30% as compared with
20 Wire No. 1.

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CLAIMS

1. A low fume wire for gas shielded arc welding comprising, as constituents, C present but less than or equal to 0.06%, 1.65 to 1.95% of Mn, 0.8 to 1.0% of Si, S present but less than or equal to 0.015%, a deposited carbon coating on the surface of the wire comprising 0.02% or less and a copper coating on the surface of the wire comprising less than 0.25% ~~Ca~~, all of the percentages being percentages of the total weight of said wire and coatings, the balance comprising iron and inevitable impurities.
2. A low fume wire for gas shielded arc welding comprising, as constituents, C present but less than or equal to 0.06%, 1.65 to 1.95% of Mn, 0.8 to 1.0% of Si, S present but less than or equal to 0.015%, 0.005 to 0.25% of Al, 0.01 to 0.25% of Ti, a deposited carbon coating on the surface of the wire comprising 0.02% or less and a copper coating on the surface of the wire comprising less than 0.25% ~~Ca~~, all of the percentages being percentages of the total weight of said wire and coatings, the balance comprising iron and inevitable impurities.
3. A low fume wire for gas shielded arc welding as claimed in claim 1 or 2 substantially as hereinbefore described.