研究論文

GMA용접에 있어서 스패터 발생에 미치는 와이어 탈산원소의 영향

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The Effect of Deoxidizers in a Wire on Spatter Generation in Gas Metal Arc Welding

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Key Words : Gas metal arc welding, Spatter, Deoxidizer, Arc stability, Metal transfer mode, Short circuit frequency

Abstract

The variation of spatter generation in gas metal arc welding with welding conditions and wire compositions was investigated and interpreted in terms of arc stability. The transition range from a short circuit mode to a spray mode in the mixed gas welding showed an unstable arc and generated the largest amount of spatters. Titanium reduced spatters only in the globular mode of CO_2 welding and silicon and manganese showed the same effect. The effect of silicon and manganese, however, was no longer seen when titanium was added simultaneously to the wire. It is believed that deoxidizers easily form oxides on the anode and make the arc stable even in DCRP welding. The wires with deoxidizers also showed low short circuit frequency, resulting in the increase of large size spatters.

1. Introduction

Spatter generation in gas metal arc welding, especially in CO_2 welding, results in poor weld quality and productivity. In general, since a more stable arc during the welding process generates less spatters, a lot of effort has been made to increase arc stability. For example, a power source with corrected inductance was developed to reduce spatters in a short circuit mode by controlling the rate of pinch[1]. If a suitable amount

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of argon gas is mixed with CO_2 gas, an unstable globular transfer mode changes to a stable spray transfer mode in certain welding conditions and in turn the amount of spatters decrease[2].

In contrast to a considerable number of investigations of the power source and shielding gas, research on the effect of wire composition on arc stability is seldom found. A. Sekiguchi reported[3] that wires containing titanium resulted in a stable arc and less spatters when a short circuit frequency in the short circuit mode was decreased. This effect of titanium was later confirmed by I. Masumoto et al[4]. In this study, the effect of welding conditions, especially current and voltage, on spatter generation was investigated first and then the effect of deoxidizing elements of a wire such as silicon and manganese was investigated and compared with that of titanium.

2. Experimental Procedure

Automatic gas metal arc welding was performed using an invertor type power source with a maximum current of 500A. Chemical composition of solid wires with 1.2mm diameters are shown in Table 1. Three bead-on-plate welds of each 30cm long were prepared on a 20×150×400mm mild steel plate which was placed in a copper chamber. Welding travel speed for each weld was 30cm/min. All spatters generated were collected and weighed after magnetically separating them from the slag particles. Spatters collected were classified to determine size distribution. US sieve series (ASTM) numbers 18 and 60 which correspond to

Table 1. Chemical composition of solid wires used. (wt%)

Wire	C	Si	Mn	P	S	Cu	Ti
KC	0.09	0.59	1.13	0.011	0.008	0.16	0.14
SR	0.08	0.62	1.08	0.013	0.007	0.29	-
MG	0.06	0.79	1.42	0.009	0.013	0.22	0.19
SC	0.08	0.84	1.47	0.009	0.016	0.13	-

mesh openings of 1.00mm and 0.25mm, respectively, were used. At each combination of current and voltage, the arc stability and droplet transfer were recorded. Arc stability was determined by the waveform fluctuation of the arc voltage and welding current recorded by a microcomputer. The recording time was 500ms and sampling frequency was 50kHz. Metal transfer was observed by high speed cinematography at 3000 frames per second.

3. Results and Discussions

Figure 1 shows the variation of the spatter amount with the arc voltage and current when welded with KC wire using 80% Ar-20% CO_2 mixed shielding gas. It varies with arc voltage and

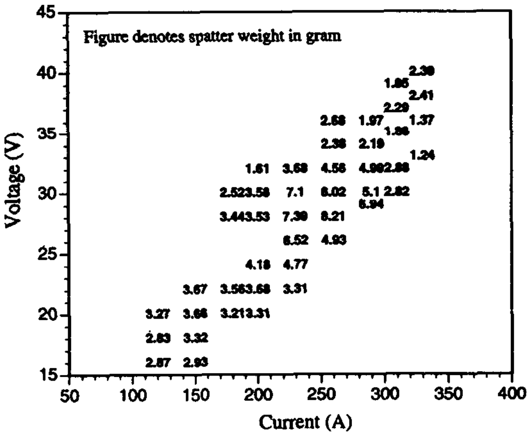

Fig. 1 Variation of the spatter amount with the arc voltage and current.

current, showing approximately 2~4 grams in a low current and voltage range (120~200A/16~24V) and 1~2 grams in a high current and voltage range (290~330A/33~41V). It shows, however, a relatively large amount (4~8 grams) at the 230~260A and 23~32V range. The metal transfer mode for each combination of current and voltage is shown in Fig. 2. The low current and voltage range which shows 2~4 grams of spatters corresponds to a short circuit mode while the high current and voltage range which shows 1~2 grams of spatters corresponds to a spray transfer mode. It is clear that the range with a relatively large amount of spatters, 230~260A and 23~32V, is the transition range from a short circuit to a spray transfer mode. Therefore, as far as spatter generation is concerned, welding in the transition range should be avoided. The typical waveforms of arc voltage in each transfer mode were shown in

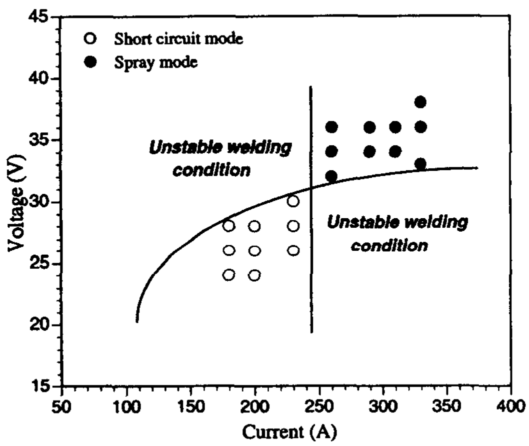

Fig. 2 Variation of the metal transfer mode with arc voltage and current.

Fig. 3. In the short circuit mode with 120A-16V, arc voltage varies regularly with a short circuit frequency of about 80Hz. In the spray mode with 330A-37V, it is almost constant. By contrast, the arc voltage is unstable and shows a lot of instantaneous short circuits at 260A-30V. One example of an instantaneous short circuit is indicated by an arrow. It is believed, therefore, that the relatively large amount of spatters generated in the transition range is due to an unstable arc characteristic such as an instantaneous short circuit even though the overall metal transfer mode in the range is short circuit or spray.

The effect of titanium in a wire on the spatter

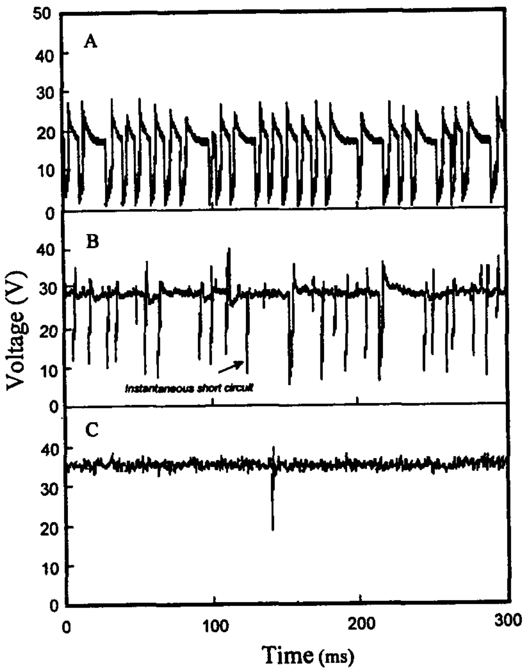

Fig. 3 Typical waveforms of arc voltage of KC wire when welded at (A) 120A-16V, (B) 260A-30V and (C) 330A-37V.

generation was investigated using KC wire with 0.14% titanium and SR wire without it. Figure 4 shows the variation of a spatter amount when welded at 120A-16V and 330A-37V using both 100% CO_2 and 80% Ar-20% CO_2 shielding gases. The spatter amounts were relatively small, about 2 grams, in all welding conditions except when welded at 330A-37V with 100% CO_2 gas, which shows 8~13 grams. The beneficial effect of titanium on the reduction of spatter generation was marked only in the globular transfer mode, showing 13.1 grams for SR wire and 7.9 grams for KC wire. The effect of silicon and manganese on spatter generation is shown in Fig. 5. The combined content of silicon and manganese of SC and SR wires is 2.31% and 1.70% respectively. Similar to the effect of titanium, the increase of silicon and manganese content in a wire reduced the spatter amount markedly only in the globular mode, showing 13.2 gram for SR wire and 4.1

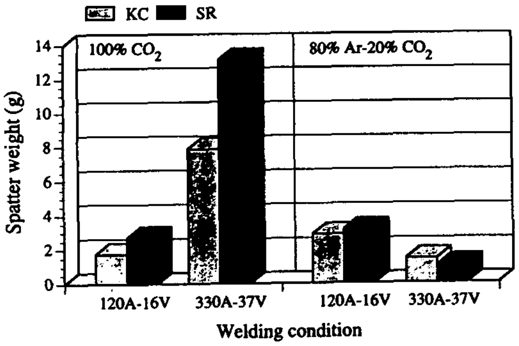

Fig. 4 Comparison of a spatter amount between KC and SR wires.

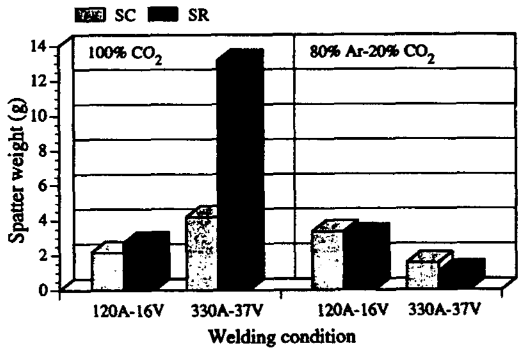

Fig. 5 Comparison of a spatter amount between SC and SR wires.

grams for SC wire.

To interpret the effect of silicon and manganese on the spatter generation in the globular mode, the waveforms of arc voltage of SC and SR wires were recorded and compared. The welding current and arc voltage was 330A and 37V, respectively. As shown in Fig. 6, SC wire has a more stable waveform than SR wire. It is well known that activated wires with an electron emissive agent have a stable arc in direct current straight polarity (DCSP) welding. E. Cushman developed a welding wire without spatters for DCSP CO_2 welding[5]. The wire was treated with a dilute solution of two alkali-metal compounds. The treatment produces a coating that is extremely thin and does not interfere with electrical contact

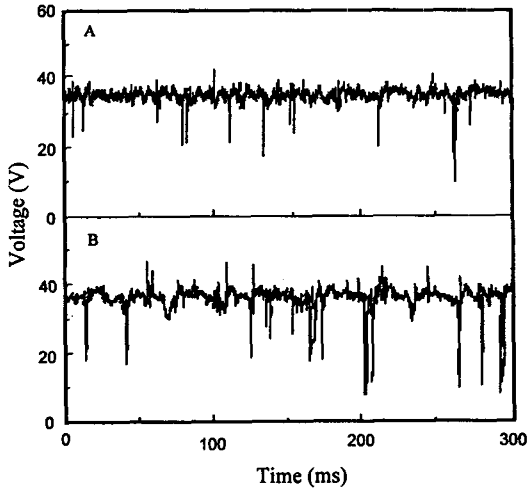

Fig. 6 Waveforms of arc voltage of SC (A) and SR (B) wires when welded at 330A-37V.

between the wire and the contact tube of the welding equipment. As direct current reverse polarity (DCRP) was applied in this experiment, electrons are emitted from a base plate instead of a wire. However, K. Ando reported[6] that the number of droplets transferred showed 30~50 times as many when 1~5% oxygen was introduced in the CO_2 gas even though welding was done with DCRP. Therefore, he claimed that an anode spot is also restricted on the oxide films as a cathode spot. Φ. Grong et al[7] assessed the chemical reactions taking place at the electrode tip, in the arc plasma and in the weld pool in gas metal arc welding. By using a water-cooled, fast rotating copper wheel as a cathode, they were able to obtain rapidly recrystallized droplets released from the electrode in the absence of a weld pool. According to their results, oxygen is absorbed from the shielding gas to form CO and manganese silicate slag at the electrode tip. Therefore, it is believed that the wire with deoxidizers easily forms deoxidation products, mainly oxides, on the droplet (anode) and makes a stable arc even in the DCRP as in this experiment.

Figure 7 shows the effect of the increase of

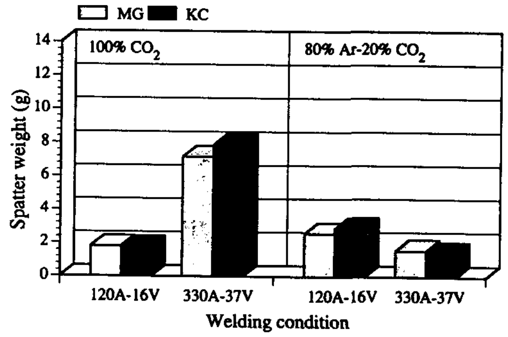

Fig. 7 Comparison of a spatter amount between MG and KC wires.

silicon and manganese content on the spatter generation when the wire was simultaneously alloyed with titanium. As expected, the largest amount of spatters was shown in the globular mode, 7.1 grams for MG wire and 7.9 grams for KC wire. The spatter amount of MG wire with 2.21% of silicon and manganese was little different from that of KC wire with 1.72% of silicon and manganese. Titanium content of each wire is almost the same at 0.19% and 0.14%, respectively. From the much stronger deoxidizing power of titanium compared to silicon and manganese, it is believed that titanium plays a more powerful effect on the spatter reduction than silicon and manganese. Accordingly almost the same spatter amount was generated in MG and KC wires because both wires have almost the same titanium content.

Figure 8 shows the comparison of current-voltage-transfer mode (CVT) diagrams of SR and KC wires when welded using 80% Ar-20% CO_2 gas. KC wire with titanium shows a contracted short circuit transfer region and an expanded globular transfer region when compared to SR wire. The same result was obtained by comparing SC and SR wire. From this result, it can be deduced that wire with a deoxidizer has a longer arc length. If a deoxidizer in the wire makes the arc length longer, the wire should have a low short circuit frequency when welded in the short circuit region.

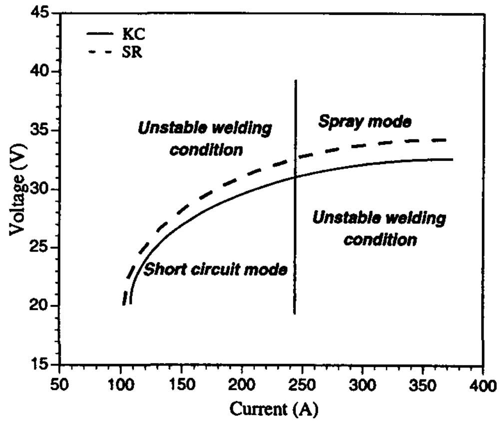

Fig. 8 The current-voltage-transfer mode diagrams of SR and KC wires.

Compared to 93Hz of short circuit frequency of SR wire, KC wire with titanium showed 82Hz when welded at 120A-16V. This confirms the results of A. Sekiguchi and I. Masumoto. As expected, the low short circuit frequency of KC wire resulted in the increase of large size spatters as shown in Fig. 9. Even though both wires show little difference in the total spatter amount, KC wire has a higher portion of large size spatters, especially larger than 1.0mm in diameter.

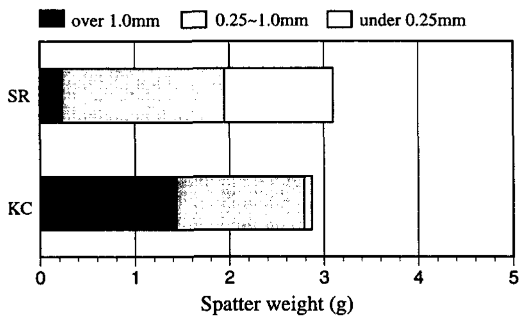

Fig. 9 Comparison of spatter size between KC and SR wires

4. Conclusions

The variation of spatter generation in gas metal arc welding with welding conditions and wire compositions was investigated and interpreted in terms of arc stability. The main results obtained are as follows:

(1) The transition range from a short circuit mode to a spray mode, 230~260A and 23~32V, in 80% Ar-20% CO_2 welding, showed an unstable arc and generated the most spatters.

(2) *In the CO_2 welding, the effect of titanium* on the reduction of spatters was marked only in the globular mode and silicon and manganese showed the same effect as titanium. The effect of silicon and manganese, however, was no longer seen when titanium was added simultaneously to the wire.

(3) It is believed that deoxidizers easily form oxide films on the anode and make the arc stable even in direct current reverse polarity welding.

(4) The wires with deoxidizer showed low short circuit frequency, resulting in the increase of large size spatters.

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