Study on new GMA welding process with duplex current feeding - Influence of welding wire -

by Masaru SETO *, Manabu TANAKA**, Shinichi TASHIRO ** and Atsuhito AOKI *

Gas Metal Arc Welding (GMAW) under pure Argon shielding gas atmosphere (pure Argon-GMAW) is suitable to obtain a high-strength and high toughness welded joint. However, it is difficult that pure Argon-GMA welding is applied practically welding structure because of arc instability. In order to perform stable pure Argon-GMA welding, duplex current feeding GMAW (DCF-GMAW) has been developed. The DCF-GMAW consists of primary GMA welding current and secondary welding current by constant-current power resource. DFC-GMAW can feed larger current near wire tip. This effect makes that weld penetration depth is deeper, weld bead shape is improved using DCF-GMAW.

Key Words: (GMA welding), (Pure Argon Gas Shielding), (Duplex Current Feeding), (Convex welding bead), (Shallow penetration)

1. Introduction

In order to guarantee safety of a high-strength steel structure, it is necessary to achieve both high strength and toughness of the welded joint. However, the toughness tends to decrease due to contamination of the weld metal by oxygen or nitrogen during welding.

Therefore, Gas Tungsten Arc Welding (GTAW) process in pure inert gas shielding gas is applied in many cases for joining high-strength steel. Though GTAW produces a high quality weld joint, it has disadvantages such as lower welding efficiency. On the other hand, Gas Metal Arc Welding (GMAW) realizes higher welding efficiency, but tends to be unstable using pure inert shielding gas. For this reason, mixture gas with argon and oxygen or carbon dioxide is generally used as the shielding gas. In this case, the toughness is largely decreased due to the addition of only small amount of oxygen or carbon dioxide 1).

In order to solve this problem, it is required to develop GMAW process in pure inert shielding gas with high stability and efficiency. GMAW faces problems such as meandering weld bead due to unstable arc caused by irregular behavior of cathode spots 2), convex welding bead due to high surface tension 3). These problems lead to welding defects such as incomplete fusion or lack of penetration in multi-layer welding.

Tanaka et al have developed the plasma GMAW process to stabilize the arc of GMAW. As a result, the arc of GMAW was adequately stabilized in pure Argon shielding 4).

It is pointed out that the convex welding bead and shallow penetration produced in the conventional GMAW is caused by the large surface tension of the low temperature weld metal. Hence, it is desirable to raise the droplet temperature of GMAW for increasing the wettability. However, in the conventional GMAW, it is difficult to increase the droplet temperature because of the unique relationship between the welding current and the wire feeding speed 4,5).

We have developed new GMAW process with duplex current feeding (DCF-GMAW) method, which enables to control the welding current and the wire feed speed independently by feeding the secondary current near the wire tip in addition to the conventional GMAW machine. In the previous study 6), deeper weld penetration was obtained in the duplex current feeding GMAW compared with that of the conventional GMAW. However, the similar effects are considered to be realized also by the conventional GMAW with short wire extension through increase in welding current. In the succeeding study 7), basic characteristics of the duplex current feeding GMAW were compared with those of the conventional GMAW with the short wire extension. Consequently, it was found that the duplex current feeding GMAW...
achieved the deeper weld penetration without an undercut unlike the case of the conventional GMA welding with the short wire extension. Differences in chemical compositions of welding wires are also considered to affect effectiveness of this process. In this study, influences of welding wires are discussed especially focusing on difference in electric resistance.

2. DCF-GMA welding equipment

The distance between the contact tip and the feeding point of the secondary current was 12mm. The duplex current feeding GMAW has two welding power sources and current feeding points as shown in Fig.1. The primary current with constant voltage characteristics and the secondary current with constant current characteristics were fed from the primary and the secondary feeding point, respectively.

3. Experimental Procedure

Welding procedure test was carried out using conventional GMAW and Duplex current feeding GMAW with pure argon gas shielding.

In the case of Duplex current feeding GMAW, Secondary current was changed from 25A to 100A by every 25A.

In welding procedure test, mild steel (JIS SM400) and stainless steel (JIS SUS304) were selected to the base metal, and the solid wires (JIS YGW15 and JIS SUS308) of 1.2mm in diameter were selected to the welding wire respectively (Table 1).

The Welding procedure test was carried out as bead-on-plate and the distance from contact tip to work distance (CTWD) was set 30mm as shown in Fig.2.

During welding, pictures of arc phenomena were taken by a high-speed video camera and welding current and voltage waveform from two power supplies were measured using a data logger as shown in Fig. 3.

Table 1 Experimental condition of conventional GMAW and DCF-GMAW

| Welding Procedure | Welding speed | Wire Feeding Speed | Shielding Gas Flow rate | CTWD | Secondary current |
|-------------------|---------------|--------------------|-------------------------|------|-------------------|
| Conventional GMAW| 50 cm/min     | 8.0 m/min          | Pure argon              | 30 mm| –                 |
| DCF-GMAW          | 30 cm/min     | 12 m/min           | 30L/min                 | 25 mm| 75,100 A          |

Fig.3 Schematic illustration of measuring method

4. Result and discussion

Fig.4 (mild steel) and Fig.5 (stainless steel) show waveforms of welding current and voltage of conventional GMAW and duplex current feeding GMAW in the case of secondary current 50A. When secondary current was changed to 25, 50, 75, 100, average values of primary current, secondary current are shown in Fig. 6 (mild steel) and Fig. 7 (stainless steel).

In the case of mild steel, the average current of conventional GMA welding is 176A. Using duplex current feeding GMA welding, average primary current is 156A, average secondary current is 50A. Total (primary + secondary) current is 30A higher than conventional GMA welding.

On the other hand, in the case of stainless steel, the average current of conventional GMA welding is 152A. Using duplex current feeding GMA welding, average primary current is 134A, secondary current is 50A. Total (primary + secondary) current is 32A higher than conventional GMA welding.

In this study, pulse arc GMA welding machine adopted Pulse Frequency Modulation was employed. In the case of increasing
secondary current, pulse frequency of primary current gets lower, 
the average current value falls down.

For this reason, it is considered that the primary current trends 
to be decreased with increase in the secondary current because of 
large voltage drop below the secondary current feeding point.

Because there is small reduction rate for primary current 
compared with the increased amount of the secondary current, 
total current (primary current + secondary current) is increased 
with increase in secondary current.

In the case of welding for mild steel with duplex current feeding 
GMAW, increment of total current is 64A (secondary current: 
100A), on the other hand, for stainless steel, increment of total 
current is 51A (secondary current: 100A).

This lower increase rate is thought to be that stainless steel 
welding wire has higher electric resistance than mild steel welding 
wire, primary welding power resource detected high welding 
voltage and reduce welding current.

The increase of total current of duplex current feeding GMAW 
is subject to influence of electrical resistance of welding wire.
The welding bead appearance and cross section of conventional GMAW and duplex current feeding GMAW in same wire feeding rate (8m/min) are shown in Fig.8 and 9. Due to addition of secondary current, penetration depth trends to be deeper and convex welding bead gets improved.

In the previous study, the measurements of droplet temperature was carried out using two color pyrometry for conventional GMAW and duplex current feeding GMAW. Average temperature of droplet surface with conventional GMAW was 1870K. On the other hand, that of duplex current feeding GMAW measured with two color pyrometry was 2160K. This temperature upshift caused by increase in total current is considered to be one reason that welding penetration gets deeper and convex welding bead profile was improved in case of duplex current feeding GMAW.

| Secondary current | Bead appearance | Cross section |
|-------------------|----------------|--------------|
| 0A                | ![0A Bead appearance](image) | ![0A Cross section](image) |
| 25A               | ![25A Bead appearance](image) | ![25A Cross section](image) |
| 50A               | ![50A Bead appearance](image) | ![50A Cross section](image) |
| 75A               | ![75A Bead appearance](image) | ![75A Cross section](image) |
| 100A              | ![100A Bead appearance](image) | ![100A Cross section](image) |

Fig.9 Bead appearance and cross section of conventional GMAW and DCF-GMAW (Stainless steel).

4. Conclusions

New welding process with the duplex current feeding was developed which can control the welding current and the wire feed speed independently by feeding the secondary current near the wire tip in addition to the conventional GMAW machine.

(1) Under the same wire feeding rate (8m/min), duplex current feeding GMAW can feed larger current from wire tip than conventional GMA welding.

(2) It was found that the droplet temperature in the DCF-GMAW was higher than the conventional GMAW. This is one factor that convex welding bead was remarkably improved and penetration depth was deeper.
The increase of total current (primary current + secondary current) of DCF-GMAW is subject to influence of electrical resistance of welding wire.

Reference

1) S. Terashima and K. K. D. H. Bhadeshia: “Change in toughness at low oxygen concentrations in steel weld metals”, Science and Technology of Welding and Joining, 11, 5 (2006), 509-516
2) T. Nakamura, K. Hiraoka: “GMA Welding of 9% Ni steel in the pure Argon shielding gas using coaxial multi-layer solid wire”, Quarterly J. Japan Welding Soc., 30, 3 (2012), 254-261
3) S.A.David, T.Debroy, J.M.Vitek: “Phenomenological Modeling of Fusion Welding Process” MRS Bulletin, 10, 1 (1994), 29-35
4) M. Tanaka, T. Tamaki, S. Tashiro, K. Nakata, T. Ohnawa, T. Ueyama: “Characteristics of ionized gas metal arc processing”, Surface & Technology, 202 (2008), 5251-5254
5) K. Yamazaki, E. Yamamoto, K. Suzuki, F. Koshiishi, K. Waki, S.Tashiro, M.Tanaka, K. Nakata: “The Measurement of Metal Droplet Temperature in GMA Welding by Infrared Two-Color Pyrometry”, Quarterly J. Japan Welding Soc., 26, 3 (2008), 214-219
6) M. Seto, A. Aoki, M. Tanaka, S. Tashiro, T. Era: “Study on new welding process with duplex current feeding”, Quarterly J. Japan Welding Soc. 34, 2 (2016), 150-157.
7) M. Seto, A. Aoki, S. Tashiro, M. Tanaka: “Comparison of wettability of beads in MIG welding process with duplex current feeding and conventional MIG welding process”, Journal of Smart Processing 6, 1 (2017), 28-32.