Welding Technology Analysis of Bypass Coupling Micro Plasma Welding

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Abstract. The method of bypass coupling micro plasma welding was introduced, and used for the research of surfacing welding experiment. Different welding parameters were investigated, the thermal cycling curves were test, and the microstructure was observed. The result shows, with the increase of bypass current, the highest temperature of thermal cycling curves decreased and the microstructure was much fine. Therefore, we could speculate that the heat input to base metal is decreasing with the increase of bypass current. The bypass coupling micro plasma welding can achieve the accurate control of arc heat, balance the heat input to base metal and welding wire. Compared with traditional micro plasma welding, bypass coupling micro plasma welding can accurately control the heat input to base metal under the condition of constant heat input.

Keywords: Bypass coupling micro plasma welding · Heat input · Microstructure

1 Introduction

Thermal input control in Fusion welding has always been the focus of welding research at home and abroad. The welding heat input in Fusion welding has an important effect on the organization and performance of the welded joint. Welding heat input is too large, there will be thick grain joints, joint strength decreased, heat affected area brittle and other issues. The welding heat input is small and can't form an effective welded joint, and easy to produce impermeability and other defects. Reasonable welding heat input can effectively ensure the quality of welded joints, but in general welding, welding heat input is always too large, for which domestic and foreign scholars have studied different methods to control the parent metal heat input, such as: pulse welding [1–3], Double pulse welding [4, 5], cold metal transfer(CMT) welding [6, 7], Double-electrode arc welding [8], and so on. Compared with traditional welding methods, these welding methods can effectively reduce and control the heat input of the base metal, in industrial production has a wide range of applications. Dual-bypass gas metal arc welding (DB-GMAW) [9, 10] is a modified GMAW process, and it is of great potential to reduce the current flow to the base metal while the total welding current is kept constant. This will not only ensure a larger welding rate of wire, while reducing the heat input of the base

S. Chen et al. (eds.), *Transactions on Intelligent Welding Manufacturing*,
Transactions on Intelligent Welding Manufacturing, DOI 10.1007/978-981-10-5355-9_6

metal [11]. According to the different forms of the bypass arc, there are different combination forms: single bypass coupling arc GMAW [12], double bypass coupling arc GMAW [13], pulse bypass coupling arc GMAW [14], double wire bypass coupling arc GMAW [15, 16].

Compared with gas welding, brazing, non-melting arc welding and other welding methods, plasma welding has energy concentration, arc stability and other characteristics, and can conduct small current welding, greatly reducing the base metal heat input [17]. Micro-beam plasma welding is a small current plasma welding with a welding current less than 63A, which can reduce the heat input of the base metal and reduce the heat affected zone of the base metal, improve the weld quality and widely used in thin plate welding [18]. But generally in the process of sheet welding, the need to fill the welding wire to get a good weld, which must increase the welding current to ensure the adequate melting of welding wire, while leading to the increase in the heat input to the base metal and the decline in welding quality. To solve this problem, we proposed a new plasma welding method based on DB-GMAW principle.

In order to precisely control the heat input distribution of the base metal and the welding wire, a method of bypass coupling micro plasma welding method is proposed. In this paper, the plasma coupling method of bypass coupled micro is introduced. Different welding parameters were investigated. During welding, the thermal cycling curves were test for the value of base-metal heat input. Meanwhile, the microstructure was observed by optical microscope to better understand the character of heat input in bypass coupling micro plasma welding.

2 Experiment

2.1 Principle

The basic principle of bypass coupling micro plasma welding is shown in Fig. 1. This welding method consists of welding torch, welding power source, wire feeder, and an adjustable resistor. Compared with traditional micro plasma welding, the difference is that the current flowing through the welding torch is divided into two parts at the tip of the tungsten electrode, part of which flows back to the positive welding power source from the workpiece and the other flows through the wire and the adjustable resistor returns to the positive welding power source. Current satisfies the relationship:

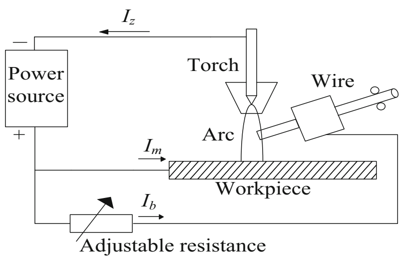


Fig. 1. Principle of bypass coupling micro plasma welding

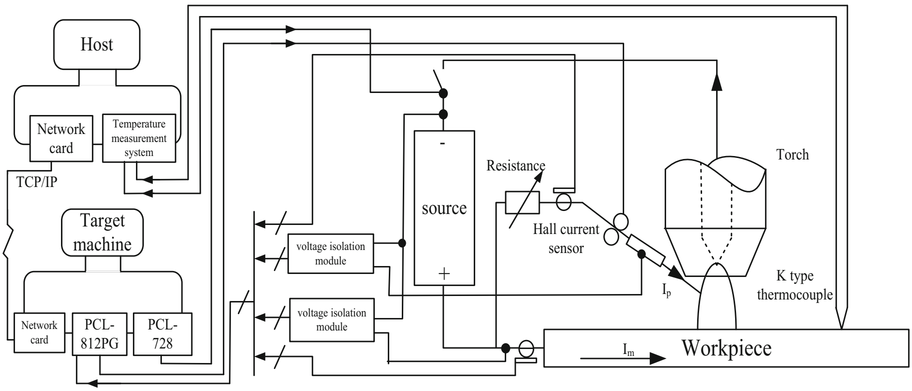
$$I_z = I_m + I_b$$

where I_z is the total current; I_m is the workpiece current; I_b is the bypass current.

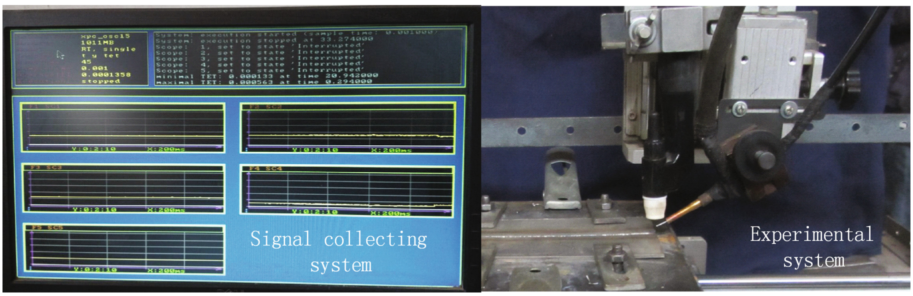
In the constant total current *I*z condition, by adjusting the resistance of the adjustable resistor, the bypass current *I*b changes, which achieves the workpiece current *I*m adjustable. At the same time, the total current *I*z can also increase. Through the adjustment of adjustable resistance, the base metal heat input can keep unchanged, which increase the melting wire current, and achieve efficient welding. By using this method, the control of heat input to base metal achieves, while the bypass current also improves the melting speed of the wire and the forming efficiency.

2.2 Experimental System

Bypass coupling micro plasma arc welding experimental system is shown in Fig. 2. It mainly includes welding systems, welding control system and signal collecting system. Among them, the welding system uses LHM-50 precision micro plasma arc welding



(a) Principle sketch[19]



(b) Experimental equipment

Fig. 2. Bypass coupling micro plasma arc welding experimental system. (a) Principle sketch [19]. (b) Experimental equipment

machine and WF-007A multi-function automatic argon arc filling machine; Welding control system includes three-axis CNC working platform, stepper motor and drive; Signal acquisition system consists of IPC, PCL-812PG data acquisition card, PCL-728 analog output card, Hall current sensor, voltage isolation module and other components. This system can realize real-time automatic control of current, voltage, temperature measurement, starting arc, arc, wire feeding. The real-time measured current and voltage is shown in Fig. 3.

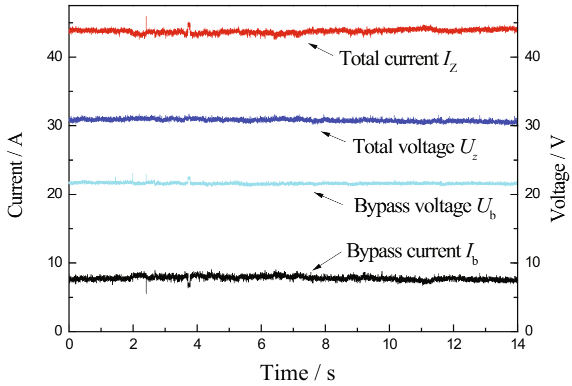


Fig. 3. The measured current and voltage

2.3 Experimental Procedure

The 304-stainless steel plate with thickness of 3 mm was used as base metal. The 0.8 mm ER304L stainless steel wire was used as filler metal. Before welding, polish with sand-paper and clean the stainless-steel plate with acetone to remove surface stains.

The surfacing welding experiment under different parameters was carried out by means of bypass coupling micro plasma arc welding on the 304-stainless steel plate. During welding, the thermal cycle curve was test. The position of test point is shown in Fig. 4. After welding, the seams under different parameter were obtained. The transverse

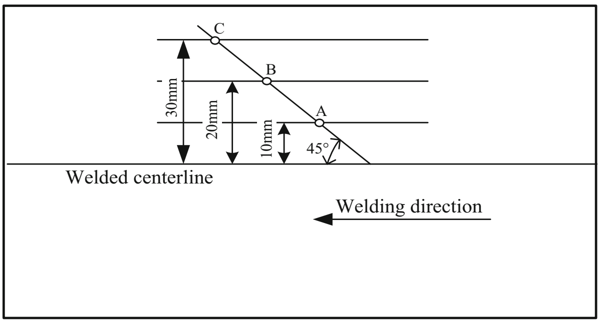
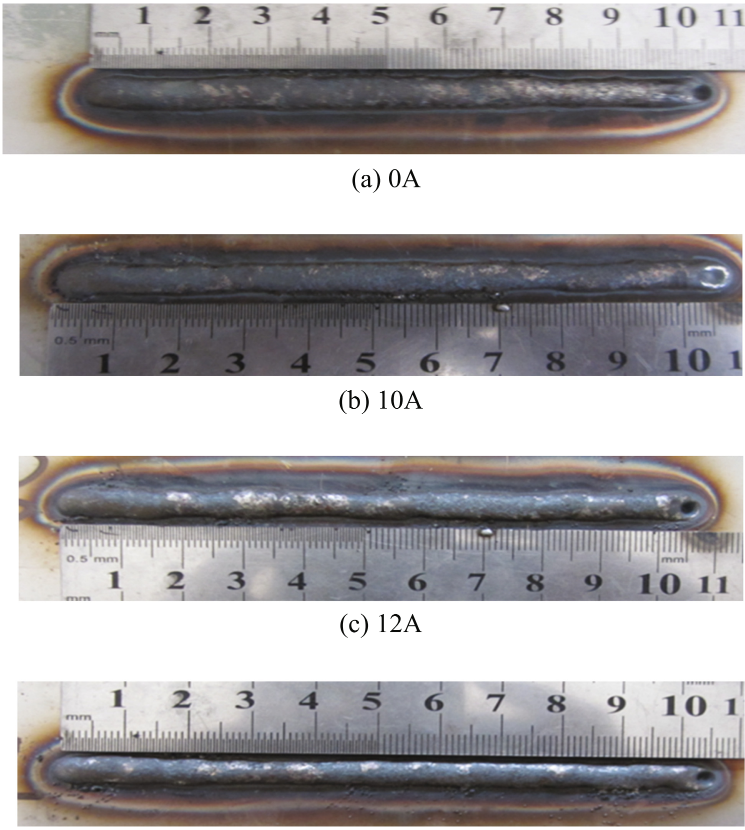


Fig. 4. Distribution of thermocouple measurement points

of seam was observed after corrosion. Finally, the microstructure of seam was observed by optical microscope. The total welding current is 50 A; The bypass currents are 0 A/ 10 A/12 A/14 A; The shielding gas flow rate is 10 L/min; The plasma gas flow rate is 0.6 L/min; The wire feeding speed is 280 cm/min; The distance of electrode to workpiece is 10 mm.

3 Results and Discussion

Under the above welding parameters, the welding seams were obtained as shown in Fig. 5. It can be seen that the weld width of seams decreased with the increase of bypass current. Then comparing the transverse of seam like Fig. 6, the weld reinforcement was found increasing with the bypass current, and the weld depth of seam was decreased gradually with the increase of bypass current. The dimension parameters of seam were measured as shown in Table 1. The decrease of weld depth and weld width shows the decrease of heat input of base metal. The weld dilution rate indicates the dilution degree



(a) 0A

(b) 10A

(c) 12A

(d) 14A

Fig. 5. The welding seams at different bypass currents

of deposited metal, and expressed as a percentage of the base metal in the weld metal. It can better express the relationship of the fusion quality of the base metal and wire. Therefore, to better understand the influence of bypass current on the heat input of base metal and the fusion velocity of welding wire, the weld dilution rate is used as an eigenvalue to cognize the influences. The weld dilution rate decreased with the increase of bypass current. It shows, when the total current stay in 50 A, the fusion quality of base metal decreased and the fusion velocity and fusion quality of welding wire increased, with the increase of bypass current. The bypass coupling micro plasma welding method can diminish the heat input to base metal, and increase the molten velocity of welding wire.

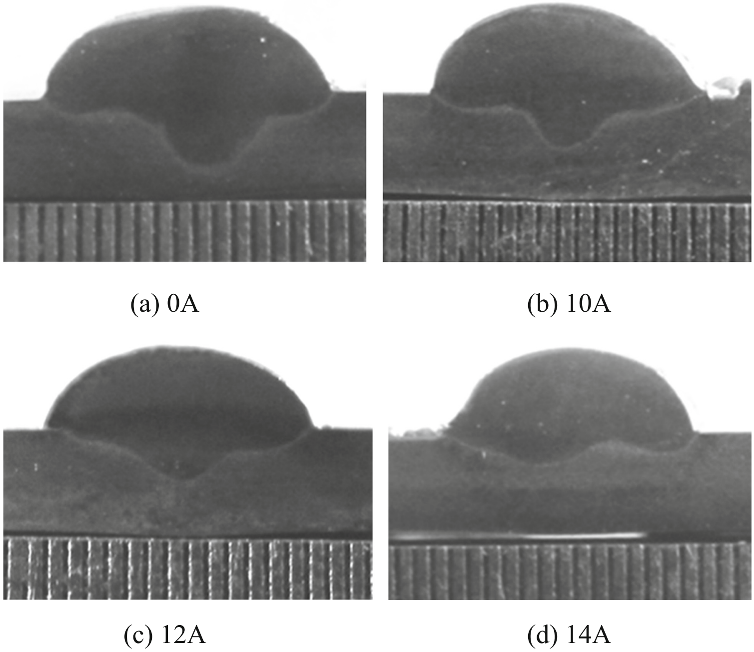
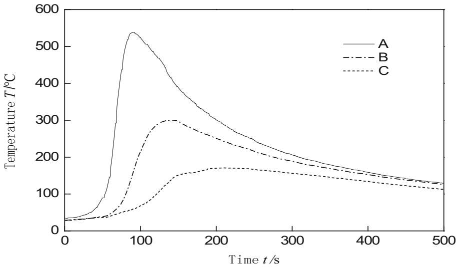


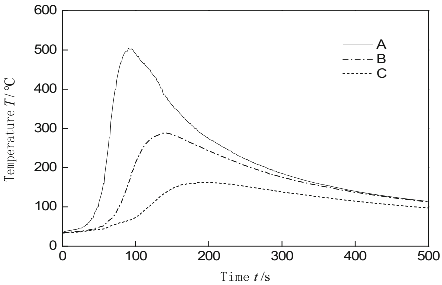
Fig. 6. Transverse of welding seams at different bypass currents

Table 1. The measurement of weld size and welding dilution rate

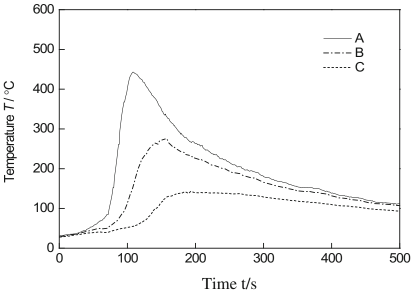
Bypass current/A	Weld width/mm	Weld reinforcement/mm	Weld depth/mm	Dilution rate/%
0	7.29	2.52	2.36	35
10	6.78	2.66	1.40	27
12	6.375	2.85	1.12	23
14	6.325	2.53	1.10	22



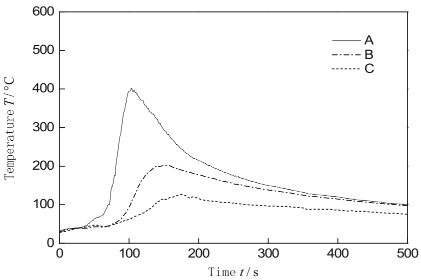
(a) 0A



(b) 10A



(c) 12A



(d) 14A

Fig. 7. The thermal cycling curves at different bypass current

To further verify the use of bypass coupling micro plasma welding method whether can diminish the heat input of base metal, the thermal cycling curve was test during the welding process. The thermal cycling curves were shown in Fig. 7. From Fig. 7, the peak temperatures of each test point under different bypass currents were obtained. Figure 8 is the peak temperature of thermal cycling curves under different bypass currents. In the three thermal cycle curves, the peak temperature of point *A* at 0 A bypass current is the highest, reaching 538.5 °C. As the bypass current *I*b increases from 10 A to 12 A, 14 A, the peak value of the temperature is reduced to 504 °C, 442.9 °C, 401.1 °C. The peak temperature of point B and point C also meet this trend. It can be proved that the heat input to base metal is decreasing constantly with the increase of bypass current.

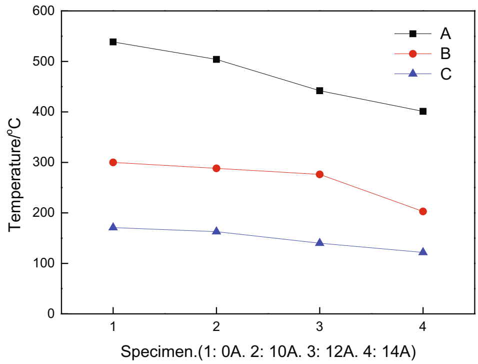


Fig. 8. The peak temperature of Thermal cycling curves under different bypass currents

The heat input to base metal consists of arc heat and resistance heat. When the total current *I*z remains unchanged, the base metal current *I*m decreased with the increase of bypass current *I*b. The decrease of base metal current causes the abatement of resistance heat. Hence due to the abatement of resistance heat, the heat input to base metal is decreased with the change of base metal current. The peak temperature was different at different base metal currents, and reductive with the decrease of base metal current as shown in Fig. 8. The fusion quality of base metal is also decreased as shown in Table 1. Meanwhile, the decrease of base metal current will lead to the increase of bypass current. The bypass current through the welding wire, and generates resistance heat. The resistance heat increases with the increase of bypass current. Therefore, the fusion velocity of welding wire increases. The weld dilution rate decreases with the increase of bypass current as shown in Table 1. The result shows the bypass coupling micro plasma welding can achieve the accurate control of heat input, and balance the heat input to base metal and welding wire. Compared with traditional micro plasma welding, under the condition of constant heat input, it can accurately control the heat input to base metal whether increase or decrease.

Figure 9 is the microstructure around the fusion zone under different bypass current. The effect of heat input on microstructure is great. In turn, Figs. 9(a)–(d) are respectively the microstructure, along with the increase of bypass current. The width of fusion zone is decreasing gradually with the increase of bypass current. And as shown in Fig. 9, the grain size of heat affected zone (HAZ) adjoins Fusion zone decreases with the increase of bypass current. The heat input to base metal will affect the growth of grain. Due to the increase of bypass current, the current to base metal reduces gradually. The resistance heat of base metal decreases accordingly, which causes the decrease of heat input and the grain refining. The coarse grain will reduce the quality of welded joint, and make the welded joint unreliable. To obtained reliable welded seam, the refined grain is needed. The results show that the bypass coupling micro plasma welding can control the heat input to base metal. Besides, because of the low heat input to base metal, it can alter the size of grain, and improve the microstructure of welded seam.

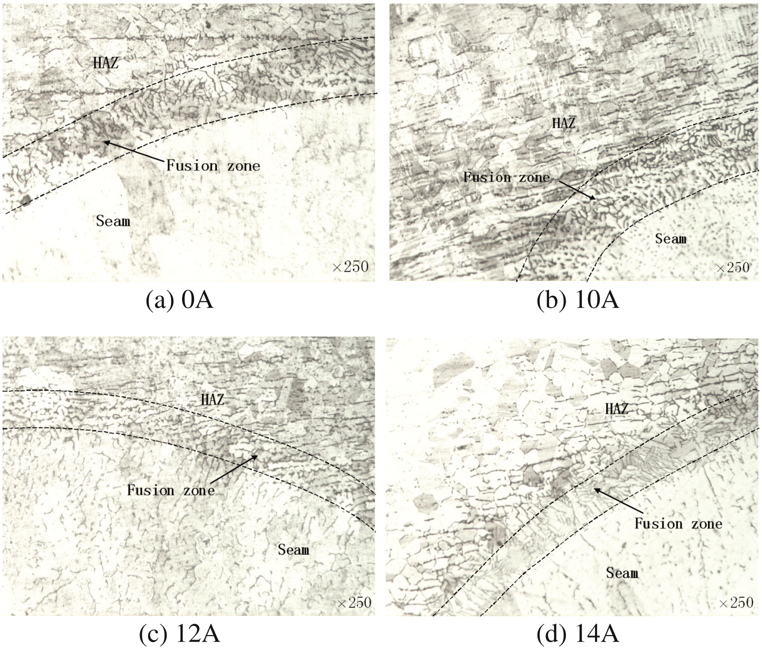


Fig. 9. Microstructure under different bypass current

4 Conclusions

- Through the control of bypass current, the bypass coupling micro plasma welding can achieve the control of arc heat, balance the heat input to base metal and welding wire.
- Under the condition of constant heat input, the heat input to base metal reduces gradually with the increase of bypass current.
- By using bypass coupling micro plasma welding, the microstructure of welded seam can be improved.

Acknowledgement. This research is supported by the National Natural Science Foundation of China (No. 51665034), the authors thank to Maohong Yang, Yonglong Yu for helping in machine repair. Special thanks to Na Wang for guiding in English writing.

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