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Effects of bypass current on the stability of weld pool during double sided arc welding

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ABSTRACT

The arc behaviour and flow patterns in the weld pool were monitored with a high speed camera and the pressure distribution of the MIG–TIG coupling arc was measured through a specially devised method involving a micro-orifice for quick ignition. The bypass current changed the geometry of the weld pool in such a way that the acting forces remained in equilibrium stabilising the pool, the weld depression was eliminated and the pressure at the arc centre decreased by a factor 4. The overall welding efficiency increased as much as the quality of the welds.

1. Introduction

Dowden et al. (1993) stated that in arc welding, the majority of the current earthed through the top surface of the base metal; in view of this, Zhang and Zhang (1998) proposed the double sided arc welding (DSAW) process to improve the weld penetration without substantial cost increase. In DSAW, two torches are directly connected to the two terminals of a single power supply and placed on the opposite sides of the workpiece to force the current flow through the thickness. Zhang and Zhang (1999a,b) suggested that in DSAW, the effect of the stirring force generated by the alternating current in the liquid metal made it possible for the thick plates to be welded using very small amperages. Experiments conducted by Mayott (2000) demonstrated that the penetration was significantly increased, as well as the welding productivity. Zhang et al. (2000) found that the symmetrical temperature profile in DSAW minimised the residual stresses in the weld and reduced the hot cracking sensitivity. Kwon and Weckman (2008) applied the DSAW process for applications such as tailor welded blanks. Zhang and Zhang (1999a,b) found that the process stability of DSAW was unsatisfactory and the depression of the weld pool could not be eliminated, which led to the weld flaws and a reduction in joint efficiency. Gao et al. (2003) reported that in DSAW, two guns were connected in series, causing the independent regulation of welding current on both sides. The workpiece was only partially penetrated when the welding current was smaller than a critical current; when the welding current approached or was larger than the critical current, the weld pool became unstable and even burn-through occurred. Much work has been performed on this particular aspect since then. For example, Zhang et al. (2002) proposed the vertical-up position welding, Jiang (2003) replaced the tungsten electrode with a water-cooled copper block and Losch and Zhang (2005) suggested multi-parameter feedback control.

To eliminate the weld depression in DSAW process with its merits maintained, the authors proposed the bypass current double sided arc welding (BC-DSAW) process. In BC-DSAW, the filler melting current remained at a high level while the base metal current was kept at a desired level. Thus, the proposed BC-DSAW has the merits of low heat input, deep penetration and high welding efficiency. The seam appearance, flow patterns in the weld pool and forces on the weld pool were investigated with and without bypass current to explore the mechanism of process stability in BC-DSAW. The arc behaviour and the flow patterns in the weld pool were monitored by the high speed camera, and the arc pressure distribution was measured experimentally. Based on these observations, the forces on the weld pool were discussed.

2. Experimental

2.1. Principle of BC-DSAW

The schematic diagram in Fig. 1 shows the principle of the proposed BC-DSAW process. A MIG torch and a root side TIG torch were

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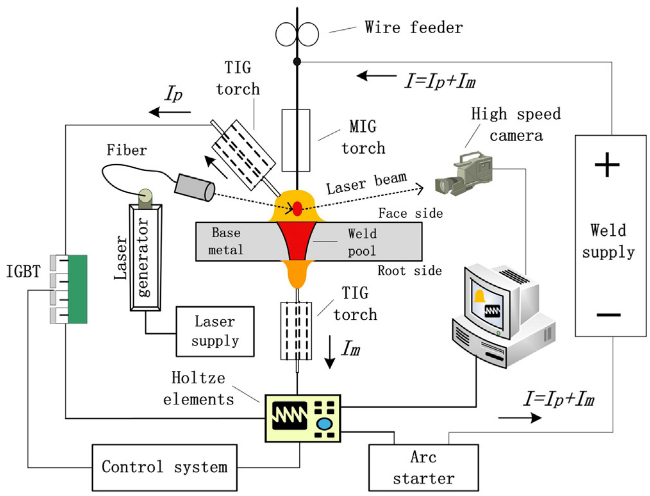

Fig. 1. Schematic diagram of BC-DSAW system.

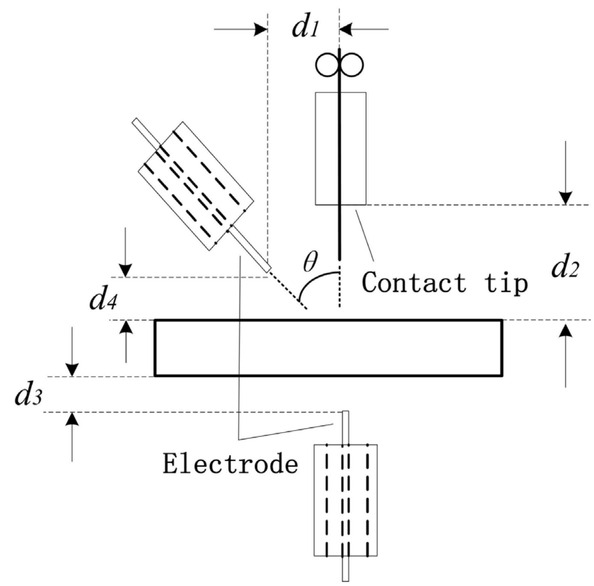

Fig. 2. Schematic diagram of position coordination in BC-DSAW system.

Table 1
Chemical composition of 304 stainless steel (wt.%).

Element	C	Si	Mn	S	P	Ni	Cr	Fe
Content	≤0.08	≤1.00	≤2.00	≤0.03	≤0.035	8.0–11.0	18.0–20.0	Balance

Table 2
Processing parameters.

Processing parameters	Details
Welding current	180 A
Bypass current	70 A
Main arc voltage	32 V
Distance between the bypass electrode and the filler wire/d_1	3 mm
Distance from the contact tip to the workpiece/d_2	13 mm
Distance from the root side electrode to the workpiece/d_3	3 mm
Distance from the bypass electrode to the workpiece/d_4	5 mm
Welding speed	0.5 m/min
Diameter of the bypass electrode	2.4 mm
Diameter of the root side electrode	2.4 mm
Flow rate of argon in the MIG torch	15 L/min
Flow rate of argon in the bypass TIG torch	5 L/min
Flow rate of argon in the root side TIG torch	5 L/min
Angle between the bypass electrode and the filler wire	45°

connected to the two terminals of the power supply; meanwhile, a bypass TIG torch was placed beside the MIG torch to decouple the total welding current into two parts: one flowed back to the power supply via the bypass torch, and the other penetrated through the workpiece and finally flowed back to another terminal through the root side TIG torch. From Fig. 1, the total welding current, which melts the filler wire, is the sum of the bypass current and base metal current. That is

$$I = I_p + I_m \quad (1)$$

where I is the total welding current, I_p is the bypass current and I_m is the base metal current.

2.2. Processing test and monitoring

The processing test was performed on 304 stainless steel with the dimension of 200 mm × 50 mm × 6 mm in the butt-joint configuration, and the filler material was 304 stainless steel wire of 1.2 mm in diameter. The material composition is listed in Table 1, the main welding parameters are provided in Table 2, and the position coordination is illustrated in Fig. 2.

In the monitoring system, an impulse laser beam was emitted at a certain wavelength differing from the arc light and was projected onto the transferring droplet and the weld pool. The reflected laser beam was acquired by the high speed camera via a filter lens of the same wavelength. The laser-emitted direction and the high speed camera must be adjusted properly to ensure the ideal laser path. In addition, the exposure time, the frame rate and the light aperture must be well coordinated to acquire clear images. At the same time, the welding current was detected by a data acquisition system, consisting of Holtze elements, a computer and an A/D card.

2.3. Measurement of arc pressure

In order to overcome the difficulty in measuring the pressure of the MIG–TIG coupling arc, a specially devised method involving a micro-orifice (0.5 mm in diameter) for quick ignition was proposed. In the actual igniting process, the bypass arc switch was first activated and the main arc switch followed immediately so that the coupling arc would appear instantly and got stable in a short period of time. Accordingly, more valid data could be collected before the droplet covered the orifice.

Fig. 3 describes the operating principle of the measuring system. The arc pressure measured by the sensor (Type: WNK808B) is

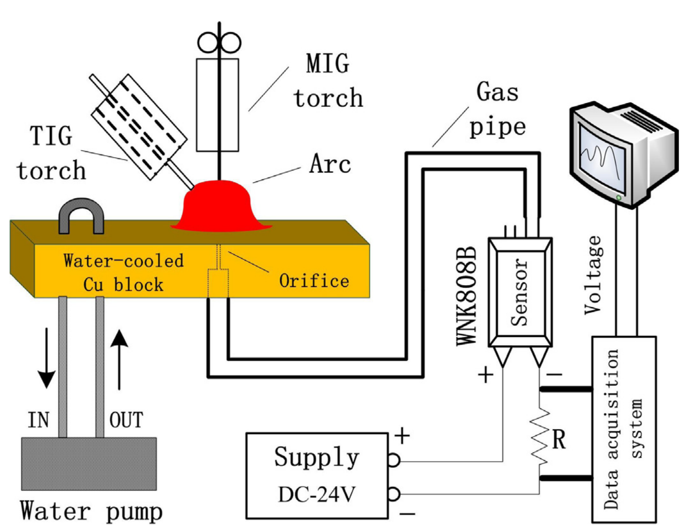

Fig. 3. Schematic diagram of the system used for the arc pressure measurement.