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Arc properties and droplet transfer characteristics in cable-type welding wire electrogas welding

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ABSTRACT

The arc properties and droplet transfer characteristics in cable-type welding wire electrogas welding were studied. A high-speed video camera and an electrical signal acquisition system were used to obtain welding arc images, the droplet transfer process and electrical signals. The results show that with an increase in welding current, the droplet transfer mode changes from globular transfer to projected transfer; the arc length decreases, the arc width increases, and the droplet size decreases. The wire extension, which ranged from 30 mm to 35 mm, has a slight effect on the droplet size, arc length and arc width. During the welding process, the arc migrates from the end of the welding wire to the necking part of the droplet. With the transition of the droplet, the arc migrates to the end of the welding wire again. As the welding current increases, the frequency of arc migration increases, and the formed droplet column becomes shorter. The rotating arc has a strong stirring effect on the molten pool, which promotes the heat transfer between the molten pool and the sidewall.

1. Introduction

Electrogas welding (EGW) is an efficient welding method developed from conventional gas metal arc welding (GMAW) and electroslag welding (ESW). Many EGW processes have been developed, including single-wire EGW, double-wire EGW, and bypass EGW. In the single-wire EGW process, the welding torch climbs along the welding direction and weaves in the thickness direction to assist the formation of the welding seam. The problem of insufficient sidewall penetration sometimes arises with the increase in plate thickness [1]. To increase the thickness of the welding plates and the sidewall penetration of welded joints, double-wire EGW is proposed, which uses two welding power sources, two wire feeders and two welding torches, forming one molten pool. However, the excessive heat input yields welded joints with inadequate impact toughness [2–4]. To reduce the heat input, bypass EGW was developed. Bypass GMAW was introduced first, which also used two welding power sources, two welding wire feeders and two welding torches, forming two welding arcs and one molten pool. Unlike double-wire EGW, the two arcs were divided into a main arc and an auxiliary arc. The main arc was formed between the first welding wire and the base metal, and the auxiliary arc was formed between the second welding wire and the first welding wire. As a result, the heat input can be reduced [5,6]. However, the control system is relatively complicated.

The welding arc and droplet transfer directly affect the stability of the welding process, thereby affecting the quality of the welded joints [7–10]. A better understanding of the arc properties and droplet transfer characteristics is essential and beneficial for forming welded joints [11–14]. However, studies on arc properties and droplet transfer characteristics in the EGW process are rarely reported.

In this research, cable-type welding wire (CWW) EGW is proposed. CWW comprises seven welding wires, with one in the centre and the others distributed uniformly around it [15]. In the CWW EGW process, only one welding power source, one wire feeder and one welding torch were used to simultaneously melt the seven welding wires, forming one self-rotating welding arc. Preliminary research results showed that CWW EGW had the advantages of high efficiency, energy saving, outstanding welding and simple welding equipment, indicating its potential use in the shipbuilding, metallurgy and petrochemical industries, where it is mainly applied to

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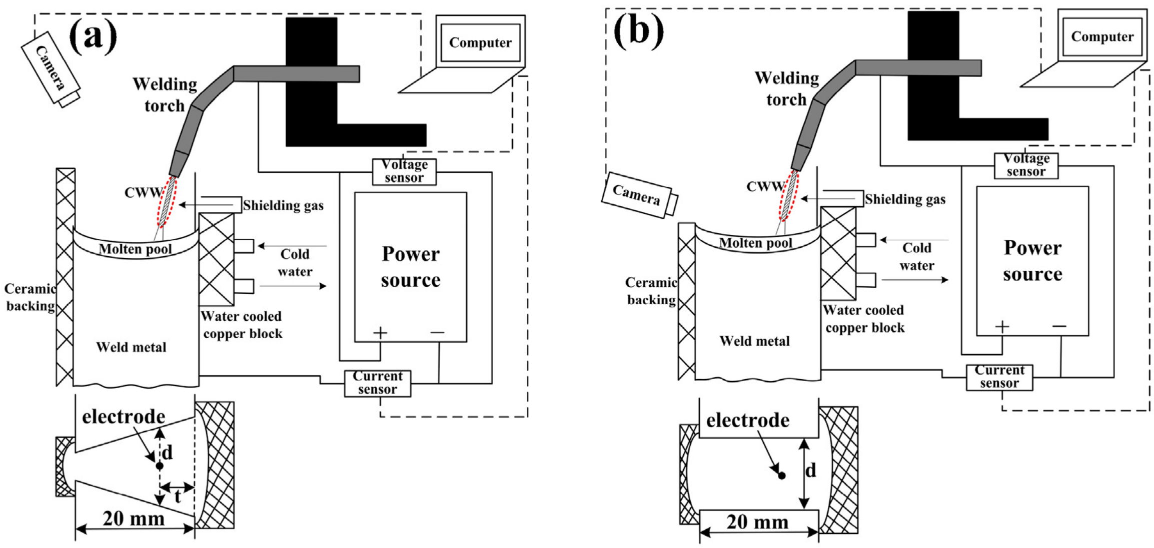

Fig. 1. Schematic of the experimental apparatus.

Table 1
Welding parameters.

Welding process	Welding voltage/V	Welding current/A	Wire extension/mm
CWW	35.5	250	30
EGW			35
		300	30
			35
		335	30
			35

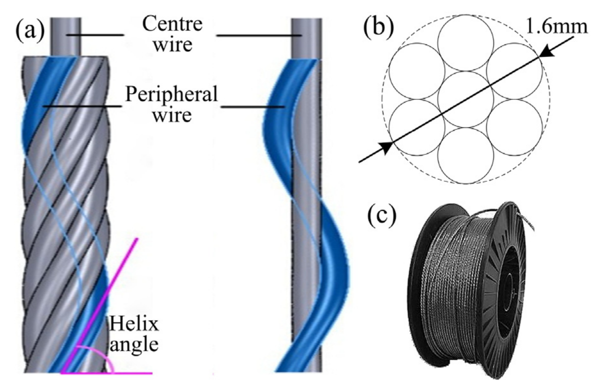

Fig. 2. Schematic of the CWW.

vertical butt welding seams [16]. In this paper, the arc properties and droplet transfer characteristics in CWW EGW were examined because of the relative lack of studies on this topic. The effect of wire extension and welding current on arc properties and droplet transfer characteristics was investigated, and the effect of arc properties and droplet transfer characteristics on welding process stability was studied.

2. Experimental procedure

Welding trials of CWW EGW were conducted. The schematic of the experimental system is presented in Fig. 1. The welding power source was operated in direct current electrode positive (DCEP) mode. The output mode of the welding power source was constant voltage, and the welding current was determined by the wire feed speed when the welding voltage setting was given. The welding voltage was 35.5 V, whereas the welding current and the wire extension were varied within a certain range, and the other welding parameters remained constant. The welding parameters are given in Table 1.

The base metal was AH36 marine low-carbon high-strength steel, and the dimensions were 500 mm (length) × 400 mm (width) × 20 mm (thickness) with a single V-groove (40°). CWW with a diameter of 1.6 mm comprised seven AWS A5.18 ER70S-G solid wires of 0.53 mm in diameter, as shown in Fig. 2. The chemical composition of the base metal and filler metal is given in Table 2. For the shielding gas, 80% Ar + 20% CO_2 was used at a constant flow rate of 30 L/min. The test specimens were obtained from the welded joints. Metallographic specimens sectioned transverse to the welding direction were polished and etched by Nital 5%.

A high-speed video camera with a frame rate of 2000 frames per second was used to acquire the images of welding arc behaviors, droplet transfer behaviors and molten pool behaviors. The welding torch does not need to weave in the thickness direction. As shown in Fig. 1 (a), the distance t between the electrode and the face of the base metal was 1/3 of the plate thickness, and the distance d between two sidewalls in the transverse direction of the electrode was 15 mm. The molten pool behaviors were observed from an overlooking view by the high-speed video camera. As shown in Fig. 1 (b), to observe the welding arc behaviors and droplet transfer behaviors from the back of the base metal, base metal with an I-groove was prepared. The distance d between the two sidewalls was 15 mm, which was the same as the distance between the two sidewalls in the transverse direction of the electrode, and a back light was projected by a laser source. An electrical signal acquisition system with a response rate of 20 kHz was developed to capture current and voltage waveforms. A LabVIEW program was designed to trigger the high-speed video camera and the electrical signal acquisition system simultaneously.

3. Results and discussion

3.1. Droplet transfer characteristics

Fig. 3 shows the droplet transfer process and corresponding electrical signals of different welding parameters in CWW EGW. Fig. 3a and b show the droplet transfer processes when the wire extension ranged from 30 mm to 35 mm with a 35.5 V welding voltage and a 250 A welding current. The sequential pictures, which have a time interval of 2 ms between two neighboring pictures,