A novel DE-GMAW method to weld steel tubes on simplified condition

Guohong Ma · Yuming Zhang

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Abstract A novel double-electrode gas metal arc welding method to weld steel tubes was investigated in this paper. The new method combines two welding torches and current sensors with welding position and angel design. In addition, a new control system was designed to improve the quality of welding seams. Experiments showed that different positions of main torch and bypass torch had different influence on welding quality. With bypass arc voltage at 35 V and suitable main welding feeder speed (WFS) at 10.2 m/min (400 in/min, 195 A), double arcs were ignited well and metal transfer was in spray mode. When the bypass WFS was at 8.9 m/min (350 in/min, 195 amps), welding seam formation and welding seam penetration were good. High-speed photos had been provided to prove the experimental results.

Keywords GMAW · Tube welding · Double electrode

1 Introduction

Gas metal arc welding (GMAW) is an important method to reach high welding quality. There have been many new developments with this conventional method recently. Palani and Murugan [1] built a model on wire feed rate in GMAW process with MATLAB software. With the model, they predicted wire feed rate successfully. Tipi [2] developed a dynamic modified model from free-flight model. The new model, derived from an automatic robot pipe system, concludes important factors of GMAW, such as transfer modes. As a result, the model can simulate real-world welding phenomena. Shao [3] and other researchers developed a dual arc method for GMAW. By monitoring liquid droplets in laser arc and GMAW arc and coupling with their algorithm, they can calculate the correct droplet size. Double-electrode gas metal arc welding (DE-GMAW) is another novel welding method because of its high metal melting rate and high welding velocity. Li and Zhang [4–7] designed different methods based on the original DE-GMAW. They developed nonconsumable DE-GMAW and consumable DE-GMAW methods. The two new methods can control metal transfer form from globular mode to spray transfer mode [8] by adjusting welding parameters. In their consumable DE-GMAW method [6, 7], they used consumable welding wire electrode to replace tungsten electrode and designed two welding machines to supply welding current based on nonconsumable DE-GMAW. Of the two welding machines, one machine is in constant voltage (CV) mode which supplies power for main arc. The other is in constant current (CC) mode that supplies power for bypass arc. Because they used consumable welding wire, high wire feed speed (WFS) can be reached. For example, in their experiments, the highest WFS is 17.8 m/min (700 in/min) when metal transfer is in spray mode. Compared with single arc welding method, double-arc welding method is much quicker and is adequate for common manufacturing process. Yu et al. [9] have done some researches in double-arc welding steel. They followed UK’s ideas and built similar systems. In their bypass arc welding system, they compared high-speed double-welding system with traditional high-speed metal inert gas method in welding aluminum alloys. Experiments showed that bypass arc could adjust
welding current and heat input in double-arc system, thus this method could have good welding quality but its welding speed is subpar under high WFS condition. In the same welding condition, single MIG method could also reach high quality and their highest speed of WFS could reach 14.5 m/min in their sheet welding process. Besides this research, Yu et al. [10] developed a double-bypass arc method in welding aluminum. They discussed metal transfer modes in different conditions. Through adjusting different bypass arc currents, the metal transfer mode could be transferred from granular mode to spray mode. Then they could acquire high welding quality. However, because there are too many factors affecting welding process, their sheet welding system was hard to make the double-bypass process precise.

All above references are focused on sheet welding process. There are few investigations focused on tube welding process with double-arc method. Compared with sheet welding process, tube welding process is more complicated. There are different welding characters in welding current, welding voltage, WFS, welding torch position, and so on. And all of these factors will affect welding formation and welding quality.

This paper focuses on the tube welding process with consumable DE-GMAW method. Section 2 introduces the welding system. Section 3 describes welding experiments. Section 4, the conclusions.

### 2 Welding system

According to the theory of the consumable DE-GMAW welding method, we designed a new system. The system theory chart is shown as Fig. 1. In this system, we used a welding machine with CC mode as the main GMAW arc power and another welding machine with CV mode as the bypass GMAW arc. In the CC power mode, welding current can be adjusted more precisely than in the CV mode. In order to acquire suitable WFS and high welding quality, the two welding machines should be provided with large energy. In this system, the CC machine can output 400 A welding current with very low variation, while the CV machine has a wide constant voltage range from 5 to 42 V. As for the welding wire feeding, the system adopts two separate wire feeders.

The system also uses one pipe to send protecting gas, a mixture of Ar2(90%) and CO2(10%). In order to obtain real-time welding information, the system uses PC and Hall sensors to monitor and display the currents of the three welding circuits, marked as I, I1, and I2 in Fig. 1. In this way, we can have more precise current data, decrease sensor error, and check circuit errors according to Eq. 1.

\[ I_m + I_{bp} = I_{total} \] (1)

For tube rotating mechanics, the system uses a rotating motor to drive the tube. For welding torches, we used a common deployment, in which the two torches were placed over the tube as shown in Fig. 2. In this way, we can decrease the complexity of the consumable DE-GMAW in tube welding process.

### 3 Welding experiments

There are many factors affecting the welding seam quality by using consumable DE-GMAW method. These factors include welding current, welding voltage, WFS, wire diameter, welding torch position and angle, rotating speed of tube, shielding gas, arc length and arc directive property, tube materials and diameter, and so on. Besides the aforementioned, the controlling process and controlling system need to be considered too.