E. Waveform-Controlled Tandem AC/AC SAW for High Productivity Welding of HSLA 100

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Introduction

High welding productivity is always a challenge faced in heavy manufacturing, energy and chemical industries. A multiple-electrode arc welding process can significantly improve the welding productivity and quality at a reduced cost because of its high deposition rate under multiple arcs. This paper investigated the influence of welding current waveform on deposition rate, welding speed and quality in a waveform-controlled tandem AC/AC submerged arc welding (SAW) of high strength low alloy steels (HSLA 100), which has heat input requirements to assure properties.

Technical Approach

A submerged arc welding system was used, which consisted of two arc-welding systems that were synchronously controlled via a network computer capable of process data logging. Before welding, the system was configured to output a square wave alternate current (AC) through the arc configuration module of the software residing inside the computer. Different sets of welding parameters associated with the configuration module were selected and customized to serve the investigation. Specifically, the time ratio of electrode negative (EN) to electrode positive (EP) and AC frequency were pre-customized using the phase generator module. Double J-groove and V-groove mockups were welded in the flat position. Two 3-mm diameter steel electrodes and a flux of neutral type were selected for two bead-layer welding. The two electrodes with 30 mm extension were spanned at a distance of 14 mm, so a single weld pool was shared between the lead and trail arc. All tests were performed with equal power (constant current and voltage settings) on each electrode but were phased 90 degrees. Under these conditions the feedback was wire feed speed (WFS) that was always higher in the trail arc. Tests were performed at constant peak current and variable EN and EP peak currents, and at different EN/EP time. Tensile strength and toughness were measured in welds made at two heat inputs using a range of welding speeds and current combinations.

Results & Discussion

The experiments showed the following. As the total welding current increased, the deposition rate increased at constant heat input, peak current, and EN/EP. For example, the welding speed and total deposition rate respectively reached 105.16 cm/min and 17.67 kg/hr for a balanced waveform, EN/EP = 1.0, at 1200 A welding current, 77 Hertz, and 2245 KJ/m heat input (Figure 1). At a constant electrode power setting, the trail arc melted more electrode than the lead arc despite the same amount of current flowing through each arc (Figure 2). For example, at a welding current of 500 A, the trail arc had a WFS of 196 cm/min but the lead arc WFS was only 190 cm/min. The preheating of a lead arc provided more energy for a trail electrode melting at constant electrode power; this was attributed to enhanced arc heating versus electrode resistive heating. The weld pool length was found to increase as current and travel speed increased at constant heat input (Figure 3). Higher EN/EP time ratio permitted welding at higher speeds by reducing weld pool length and improving solidification stability. As the time ratio of EN to EP increases, more electrode was melted at constant arc power. For example, the total deposition rate at 9.0 EN/EP time ratio was 17.28

kg/hr compared with 14.57 kg/hr at 1.0 EN/ EP time ratio at 1200 A with a waveform offset of -2757. The higher potential at the electrode during the EN period was a major contributor to the higher deposition rates. The weld quality, which was based on the ultrasonic inspection and mechanical testing data exceeded the application requirements and single electrode SAW data even at the high heat input of 2955 KJ/m. Figure 5 showed a typical cross section of welded joints.

Conclusion

Waveform-controlled tandem AC/AC SAW dramatically increased the welding productivity because of its achievable high current, high speed, and high deposition rate. With an unchanged heat input setting, a higher deposition rate was achieved by taking advantage of the EN heating and the stability provided by advanced waveform controls. The mechanical properties exceeded the high quality requirements of HSLA 100.

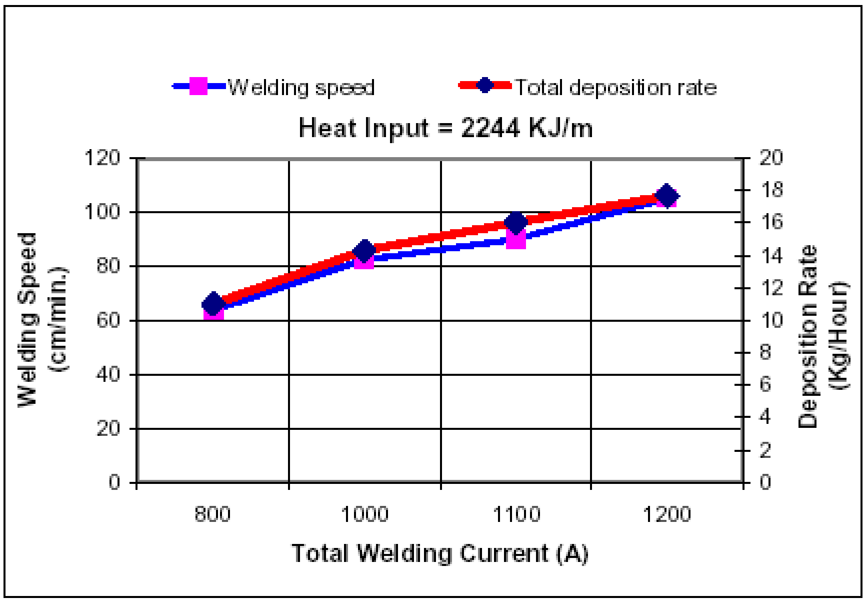

Figure 1. Welding Speed and Deposition Rate versus Total Welding Current at Constant Peak Current, Heat Input and EN/EP Time Balance.

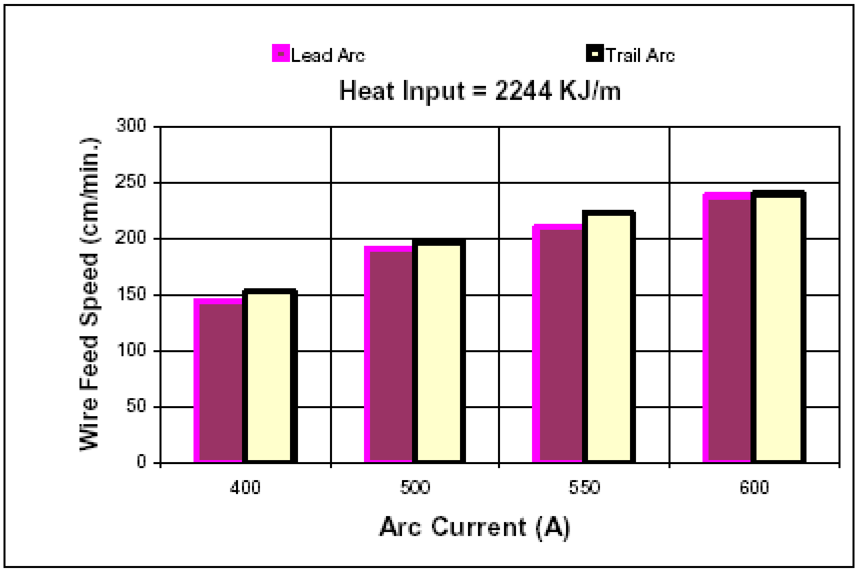

Figure 2. Lead and Trail Electrode WFS versus Currents at Constant Peak Current, Heat Input, and EN/EP Time.

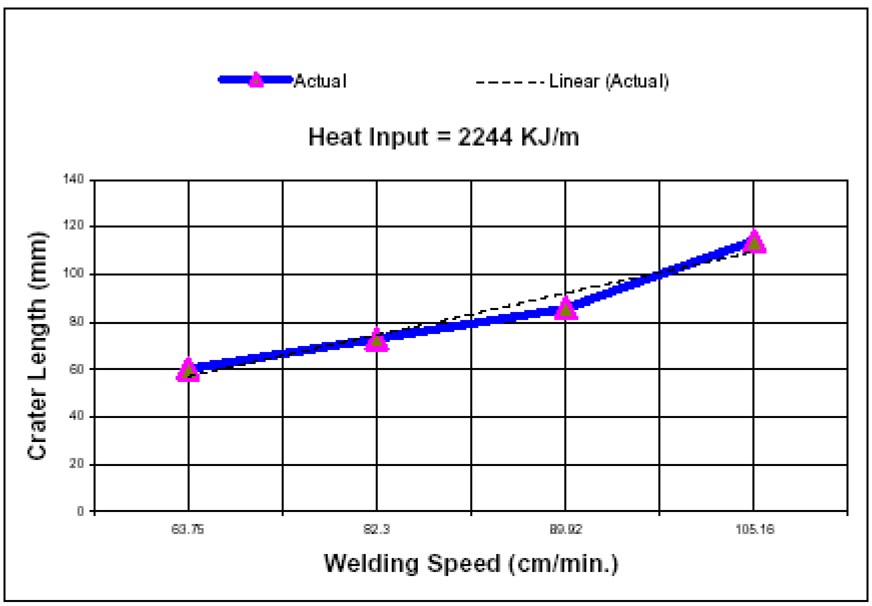

Figure 3. Crater Length Measured at Different Currents at Constant Peak Current, Heat Input, and EN/EP Time

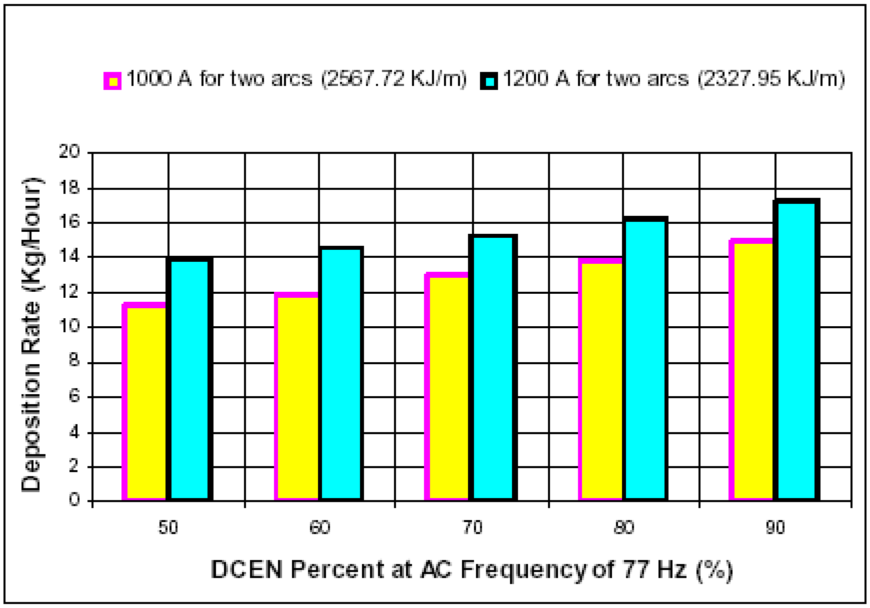

Figure 4. Deposition Rate for Different EN/EP Time at Currents of 1000 A and 1200 A at Constant Heat Input

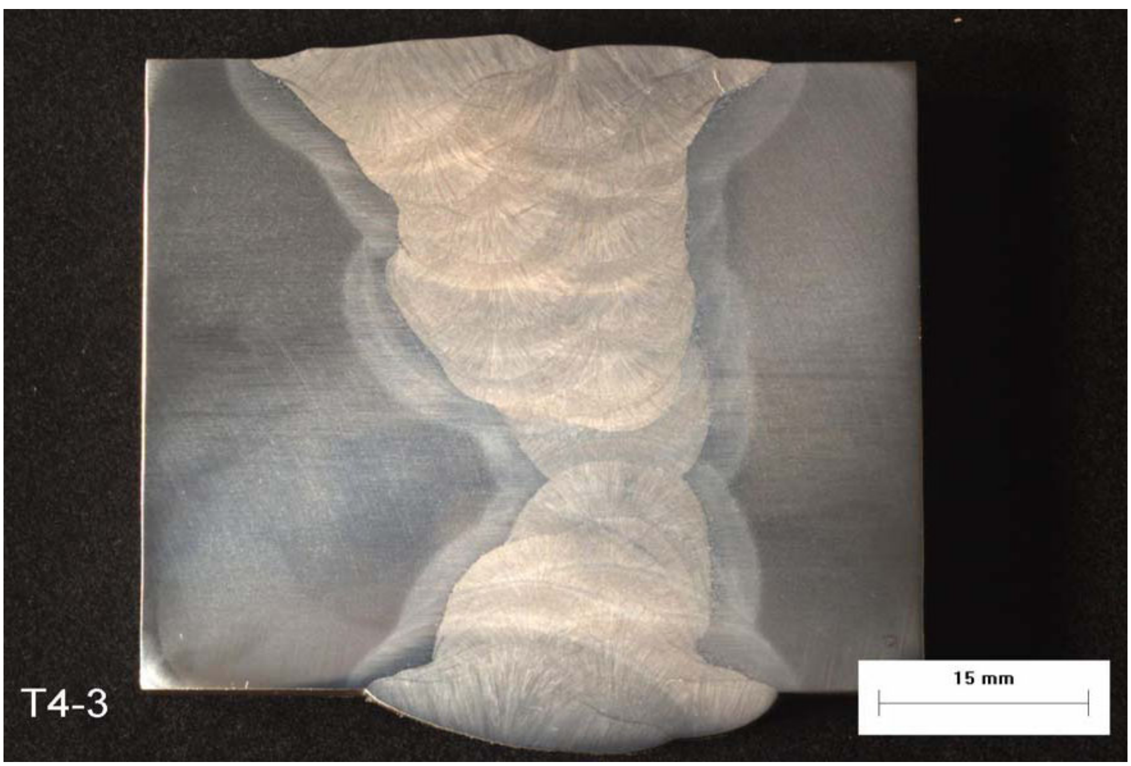

Figure 5. Tandem SAW Weld Cross Section of Double J-groove Test