The Effect of Weld Parameters on Irreversible Hydrogen Trapping in High Strength Low Alloy Weld Metal

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Introduction/Background

Hydrogen-assisted cracking is encountered in the fabrication of welded steel structures especially when higher strength steels are welded. Heat treatment methods to mitigate cracking in welds require removal of sufficient hydrogen that can raise the cost in fabrication.

The removal of hydrogen from the weld by heat treatment as a solution has been studied and proven to be an effective method [1]. However, new solutions have been introduced to reduce or control the hydrogen and to potentially eliminate the high cost of weld heat treatments. Such methods are to control the absorption and transport of hydrogen during the arc welding process. These methods seek to control the initial amount of hydrogen, i.e. the flux components in flux welding processes; to reduce the activity of hydrogen in the weld arc by the use of fluorides [2]; and to control the distribution by hydrogen trapping [3,4].

However, the study of hydrogen absorption during welding due to changes in weld parameters has been limited [5,6]. The effect of weld parameters and hydrogen absorption has not been fully understood, especially when irreversible hydrogen traps are used. These irreversible hydrogen traps and the presence of hydrogen in the weld arc can affect the amount of hydrogen being absorbed and their distribution in the weld metal which are dependent on the weld parameters. The effect of weld parameters in the presence of an irreversible hydrogen trap has been investigated.

Procedure Section

Diffusible hydrogen measurements were carried out in conformance with the ANSI/AWS A4.3-93: “Standard Methods for Determination for of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding” where gas chromatography was used for the detection and quantification of hydrogen.

To evaluate the irreversible hydrogen trapping, the Kissinger method [7], which is derived from a thermal desorption technique, was used to characterize the irreversible trapping behavior and its properties such as binding energy, trap type classification (reversible and irreversible), and partitioning of hydrogen to different trap types. Metallographic, chemical analysis, and XRD techniques were used to further investigate the role of the microstructural components including irreversible hydrogen traps, in the form of inclusions, on trapping behavior.

Data acquisition was taken to monitor the welding voltage, current, travel speed, gas flow and the observed metal transfer modes were recorded.

Results and Discussion

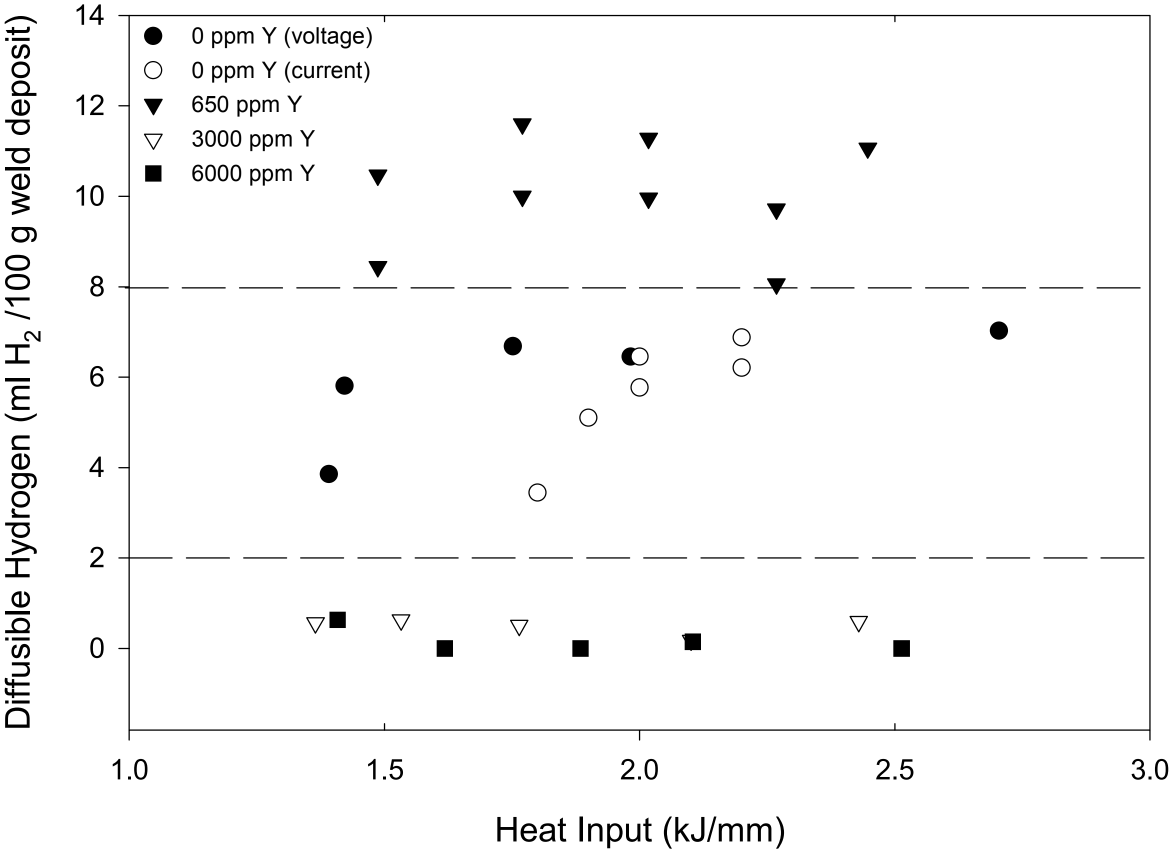

Figure 1 The effect of heat input on the diffusible hydrogen reduction in High Strength Low Alloy (HSLA) steel weld metal by varying the amount of yttrium additions in HSLA metal cored welding wire.

Yttrium ferro-additions have demonstrated significant reductions in weld metal diffusible hydrogen content []. The optimum set of welding process parameters for the effective use of the yttrium additions has been determined and demonstrated [8]. The addition of yttrium in the welding arc allows lower voltages and currents for the welding arc due to the lower ionization potential of yttrium than that of argon. These welds were made with 0.1 percent hydrogen in argon shield of gas and the welding voltage at 30 volts. The affect of yttrium additions to the amount of heat, i.e. heat input, can be seen in figure 1. The heat inputs ranged from 1.3 to 2.7 kJ per millimeter. The heat input is an indication of the cooling rate that the weld pool will experience. A slower cooling rates, or high heat inputs, more time is available for diffusion of hydrogen to be trapped by yttrium type traps and the effusion of hydrogen from the weld pool.

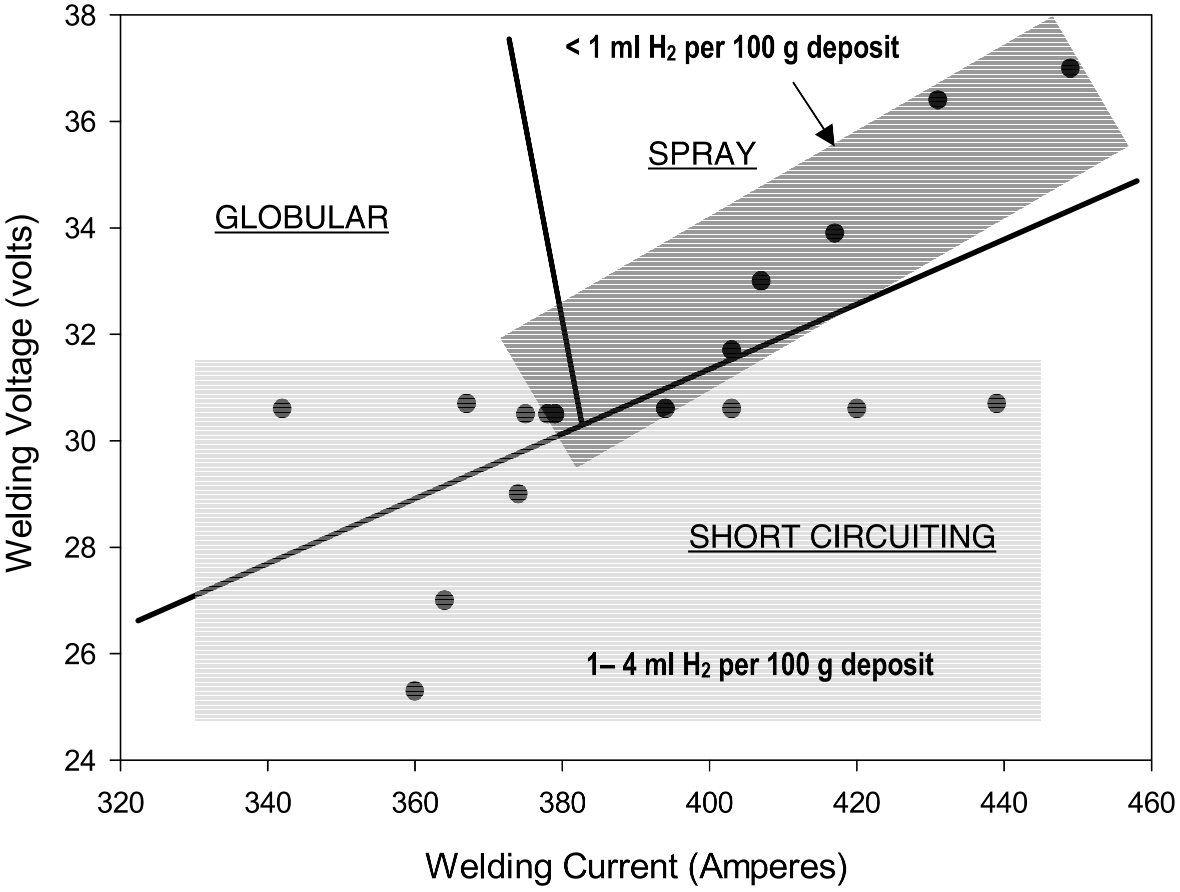

Figure 2 Metal transfer mode plot of diffusible hydrogen content for the three main modes of GMA welding of HSLA steel in the presence of yttrium trap formers.

A metal transfer mode plot (figure 2) was made for gas metal arc (GMA) welding process with a corresponding mapping of diffusible hydrogen contents. Metal-cored steel wires with yttrium as a weld metal hydrogen trap were used. Depending on yttrium and sulfur contents, yttrium oxide and/or yttrium oxy-sulfide inclusions form in the weld metal. The metal transfer modes were observed and recorded during welding and mapped accordingly with the welding voltage and current. Heat input ranged from 1.4 to 3 kJ per millimeter and shows a range less than one up to four millimeters of hydrogen per 100 g weld deposit.

The effects of voltage, current, travel speed, polarity, and oxygen levels have also been examined. An optimum operating window is shown for welds made resulting in less than one millimeter of hydrogen (per 100g deposit) content as shown in Figure 2. In the spray mode, yttrium is effectively transferred across the arc and has the necessary time during transfer across this arc for this size of droplet to produce sufficient yttrium compounds to serve as hydrogen trapping site.

Conclusion

High levels of yttrium addition to the metal cored wire, 3000 and 6000 ppm yttrium, resulted in low diffusible hydrogen below 1.5 ml hydrogen per 100g weld deposit unaffected by weld voltage or current. Low levels of yttrium, 650 ppm, also was unaffected by weld voltage and current and showed that no reduction in the diffusible hydrogen content was measured.

Metal transfer mode plots with weld metal diffusible hydrogen values show that spray transfer mode promotes diffusible hydrogen contents lower than one ml hydrogen per 100 g weld deposit whereas globular and short circuiting transfer modes have a range from one to four ml hydrogen per 100 g weld deposit for the selected welding parameters.

Further testing over the complete range of welding parameters and the measurement of hydrogen partitioning between diffusible and trapped hydrogen can give a much fuller understanding of hydrogen absorption and the interaction with hydrogen traps.

References

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