The Effect of Weld Metal Copper Content on HAZ Cracking in Austenitic Stainless Steel welded with Al-brass

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Abstract

Austenitic stainless steel has good weldability but is sensitive to hot cracking such as solidification crack and liquation crack. In this study, the specimens of dissimilar metals made between austenitic stainless steel and Al-brass were welded by GTAW process using four different filler metals. Cracks were detected in the heat-affected zone of the stainless steel when welded with CuAl, CuSn and NiCu filler metals, but no cracks were detected a Ni filler metal was used. The cracks propagated along the grain boundary in the heat affected zone near the fusion line to base metal of 316L stainless steel. The cracks were located inside the weld bead with very fine hairline crack. All cracks initiated at the fusion line and moved forward in the base metal. From energy dispersion spectroscopy (EDS), Cu peak was detected only in the crack-opening area

1. Introduction

With rapid advancements in various transport industries, the quantity of transported goods is increasing daily, especially most of crude oil is transported by tankers. Heating coils are installed inside the crude oil tankers to prevent oil solidification (to make loading and unloading easy). The steam at 160℃ flows inside the coils at 10-12 kg f/㎠ pressure, and it outside is exposed to the crude containing H_2O, NH3 and Cl. Heating coils are made of material that have good heat-conductivity and corrosion resistance to chlorine atmosphere thus, Al-brass is used to make there coils. This material is also lighter than other materials. To prevent the gas explosion, that may occur when crude oil is in transit, the inside of the oil tanker is filled not only with oil but also with inert gas in a secured space (most engine exhaust gas is used as this inert gas because it does not contain oxygen). But this engine exhaust gas contains HNO_3, NH_3, and H_2S which are harmful elements that may accelerate corrosion. As a result, stainless steel, which has corrosion-resistance superior to Al-brass pipe, is used in this area, thus Al-brass is welded to the stainless steel. The welding must may be done by brazing(Refs,1-3). But if there is a wide gap between pipe and sleeve or where repair welding is required, arc welding is preferred. In this study, the specimens of austenitic stainless steel were welded to Al-brass by gas tungsten arc welding(GTAW). The appearance of cracks, microstructure of cracks, and the effect of Cu on the liquation cracking was studied for four different filler metals.

2. Experimental Procedure

2.1 Materials and specimens

The specimens were fillet welded (single pass) by gas tungsten arc welding (GTAW) between austenitic stainless steel (316L) and Al-brass joint. The size of the test specimen was 300mm (11.8 in.) in length x 44.5mm (1.75 in.) in diameter x 2mm (0.08 in.) in thickness.

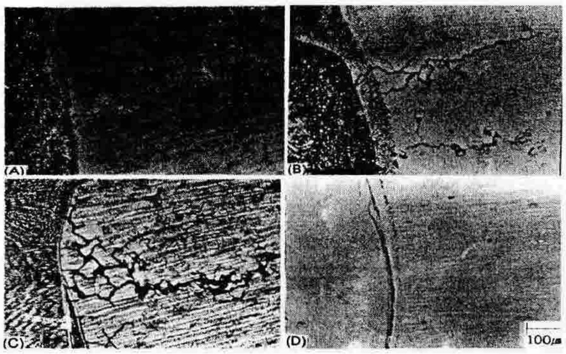
2.2 Welding condition

Gas tungsten arc welding(GTAW) was performed using four filler metals (3.2mm diameter, 15L/min flow rate, 100% Ar gas, cold wire feed).

3. Result and Discussion

3.1 Cracking

Cracks were not detected on the surface of weld bead, but very fine hairline cracks were detected inside the weld bead. To check the positions and lengths of the cracks, the specimens were cut into longitudinal sections perpendicular to the weld line. Cracks were detected in the heat-affected zone of stainless steel welded with CuAl, CuSn and NiCu filler metals only, Cracks were not detected in that joint welded with Ni filler metal. Fig. 1 shows the crack morphologies of the welded joint in (A), (B), and (C). It can be seen here that the cracks propagated along the grain boundary in HAZ near the fusion line and their shapes indicated liquation cracking.



A CuAl filler; b CuSn filler; c NiCu filler; d Ni filler

Fig. 1 Microstructure of stainless steel weld joint depending on filler metals

HAZ liquation cracks were as short as 2-3 times the diameters of a grain and propagated in the direction of the HAZ. This type of cracking is known as grain boundary cracking and is known to be produced in the partially melted zone or grain boundary of HAZ. Mechanisms that describe HAZ liquation cracking can be divided into two general categories: those that support a grain boundary penetration mechanism and those in which grain boundary segregation is important.

The penetration mechanism for HAZ liquation cracking involves the interaction of a migrating HAZ grain boundary with liquating matrix particles such as carbide, sulfides, borides, etc (Ref. 4). Despite the utility of the grain boundary penetration mechanism, HAZ liquation cracking is also sometimes encountered in material where constitutional liquation does not occur. The segregation model in its simplest formprovides for solute/impurity element segregation to grain boundaries, thereby reducing the melting temperature of the boundary relative to the surrounding matrix. The cracks in the HAZ adjacent to the fusion line can be detected more frequently than in any other location. Liquation cracking occurs during the heating cycle of the welding process. The direction of stress during the solidification and cooling cycle will determine the crack orientation.

4. Conclusion

The specimens of Austenitic stainless steel and Al-brass joint were welded by gas tungsten arc welding(GTAW). The properties of crack, microstructure, and the effect of Cu on liquation cracking were investigated for four filler metals. The results of this study are summarized as follows:

1) Cracks were detected in the heat-affected zone of stainless steel welded with CuAl, CuSn and NiCu filler metals, but cracks were not detectedin the heat-affected zone of welds made with Ni filler metal.
2) Cracks propagated along the grain boundary in heat affected zone near the fusion line to the base metal of 316L stainless steel.

3) From energy-dispersion spectroscopy (EDS), Cu peak was detected in the crack-opening area only.
4) Cracks were not detected in the surface of weld bead, but were detected inside weld bead as very fine hairline crack.
5) All cracks initiated at fusion line and moved towards in the base metal.

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