

Effect of Welding Variables on the Microstructure of Duplex Stainless Steel Welds

Prof. Maria Carolina Payares - Asprino (Universidad Simon Bolivar, Venezuela)

Prof. R. Evans(University of Wales Swansea), U.K. , Prof. Stephen Liu (CSM, USA)

Introduction:

Effective weld design can produce physical and mechanical properties within the weld metal that approach those of the parent base metal. The mechanical properties of a welded material depend on the microstructure, which, in turn depends on the phase transformation characteristics as governed by the continuous-cooling transformation (CCT) diagrams. The heating and cooling rate, determined by the welding conditions (welding process, arc current, arc voltage, welding speed, heat input), control the temperature-time cycle at every point of a weldment. Hence, it is extremely important to study the effect of welding variables on the microstructures of the fusion zone and heat-affected zone in order to optimise the weld mechanical properties.

A duplex stainless steel (DSS) was chosen for this research. Compared with austenitic stainless steels, duplex stainless steels have several advantages, for example, higher strength and superior resistance corrosion. However, a major hindrance for their application is the weakness of the weld metal and the heat-affected zone (HAZ) because of their changes to the ferrite to austenite fraction ratio..This study focused on the microstructural characterization under different welding conditions. The percentage of phases was experimentally determined and estimated using theoretical and experimentally developed models.

The data from thermal cycles determined as a function of time provided from thermo coupled welds was used for thermal simulation using the Gleeble-3500 simulation.

Technical Approach:

Several butt welds were deposited using Gas Metal Arc Welding (GMAW) on DSS plates with a thickness of 6.35 mm and using Submerged Arc Welding process (SAW) on 12.7 mm thick plates under different welding conditions. Temperature-time history for each of the welds was recorded in the HAZ. As recommended by the ASTM 4815 and A789 procedures for GMAW process, an ER 2209 electrode wire of 1.00 mm diameter was used. The SAW welds were produced using a 22.8.3L electrode of 2.40 mm diameter, as recommended by AWS/ ASME SFA-5.9 ER 2209. The microstructure of the weld metal and the HAZ using optical microscopy (OM). The etching solution used for OM was Kalling # 2 (5gr CuCl₂, 100ml H₂O, 100ml HCl and 100ml ethanol).

The welding parameters: heat input: 0.7-2.6, numbers of runs: 3, shielding gas 99.95 % argon, welding position: PA, weld type: butt weld,

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Results/Discussion:

The increasing in heat input, cause an increases in peak temperatures of the heat-affected zone. The temperature reached in the HAZ for the lowest heat input was 351°C and while for maximum value of heat input, the peak temperature was 704°C. This increased in temperature promotes the transformation of δ -ferrite in σ phase + λ_2 . Therefore, the gleeble specimen microstructures contained very fine secondary particles, within the δ -ferrite phase. Secondary particle were already fount to precipitate at the irregular interfaces between γ island and the δ -ferrite matrix. These interfaces are well known as the preferential nucleation sites for the heterogeneous precipitation of σ phase. The size and amount of σ increased with higher heat input, and σ phase eventually became coarse and irregular shape. Optical metallographic of the specimens, which reached highest temperatures, clearly revealed that σ phase formed along γ/δ interfaces and grew into δ -ferrite region.

Percentages of phases (γ and δ) in fusion zones welds calculated by both theoretical of Moving Heat Source and Pseudo-Steady –Thick Plate Solution and experimental model developed by Payares, C. and et. al (IMECE2003-43600) and chemical analysis are very reliable to obtain the percentage of ferrite in the weld metal. However, experimental model gave the accurate percentage of ferrite comparing to experimental values. The results showed a decrease in ferrite level with increases in HI, for highest HI the cooling rate was 135.92°C/sec. It due to the undercooling achieved during rapid solidification, for higher cooling the austenite is kinetically favoured. On the contrary, at lower HI the cooling rate was 23.37 °C/sec.

Conclusions:

- Microstructure of the region within the HAZ just below the fusion line demonstrated a partially melted zone with wetting of segregated HAZ δ -ferrite grains by liquid. High values of heat input promote this effect.
- The experimental model gave more reliable results of the percentages of phases in fusion zone weld than the theoretical model.
- Microstructures in Gleeble specimens show that intermetallic σ phase precipitated at the interface of γ/δ and grew into the δ -ferrite region