The Effect of CWTSAW on the Toughness of Heavy-Gauge X70 — Part II: Correlating Microstructure with Charpy Toughness

The effect of martensite-austenite morphology on Charpy toughness for cold-wire tandem submerged-arc welded X70 steel was studied

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Abstract

The effect of martensite-austenite (MA) constituent morphology, prior austenite grain size, fracture length, and notch placement on the Charpy toughness and micro-hardness in the heat-affected zone (HAZ) of heavy-gauge (19.1 mm thick) X70 microalloyed steel welded by cold-wire tandem submerged-arc welding (CWTSAW) was studied. In Part I, a series of single-pass CWTSAW samples were made using cold wire feed rates (effective heat input) of 0 mm/s (2.9 kJ/mm), 16.9 mm/s (2.6 kJ/mm), and 33.9 mm/s (2.3 kJ/mm). In Part II, the absorbed energy values at –10°C and –30°C ranged widely from 240 J (max) to 8 J (min) for effective heat inputs of 2.9 kJ/mm and 2.3 kJ/mm. The higher Charpy energies for the 2.9 kJ/mm and 2.3 kJ/mm samples tended to occur when the notch center was located in the fine-grained HAZ (FGHAZ), and much of the crack propagated through the FGHAZ. The lower Charpy energies for the same heat inputs occurred when the notch center was positioned in the coarse-grained HAZ (CGHAZ), which had a significant amount of coarse-stringer MA constituents. The 2.6 kJ/mm samples had consistently high absorbed energy results (> 190 J), whether the notch center was positioned in the coarse-grained HAZ or the FGHAZ. The number of coarse-stringer MA constituents in the CGHAZ of 2.6 kJ/mm sample was the lowest. A severity parameter (SP) was developed to correlate the severity of coarse-stringer MA and crack length in the CGHAZ/FGHAZ. The SP value increased as the number of coarse-stringer MA and fracture length in the CGHAZ increased, which correlated to reduced Charpy toughness.

Keywords

- Cold Wire Tandem Submerged-Arc Welding
- Martensite-Austenite Morphology
- Prior Austenite Grains
- Charpy Toughness
- Micro-Hardness

Introduction

Cold-wire tandem submerged-arc welding (CWTSAW) is a welding process consisting of three electrodes: a lead electrode, a trail electrode, and a cold electrode (no current is applied to this wire). CWTSAW was developed for heavy gauge microalloyed steel line pipe (> 17 mm) to reduce the effective heat input of tandem submerged-arc welding (TSAW) and to maintain and improve the coarse-grained heat-affected zone (CGHAZ) toughness.

In Part I of this two-part article (Ref. 1), the effects of effective heat input (cold wire feed rate) on the area (Area) and aspect ratio (AR) distribution of the martensite-austenite (MA) constituents in the CGHAZ and fine-grained heat-affected zone (FGHAZ) and the size of the prior austenite grains (PAGs) in the CGHAZ were studied. The PAG size and MA constituent morphology (Area and AR distribution) were measured using optical microscopy. The average PAG size was reduced from 139 µm to 83 µm as the effective heat input was decreased from 2.9 kJ/mm (0 mm/s cold wire feed rate) to 2.3 kJ/mm (33.9 mm/s cold wire feed rate). The total number of MA constituents and the Area fraction of MA in the CGHAZ was lowest for the intermediate heat input of 2.6 kJ/mm (16.9 mm/s cold wire feed rate). This behavior was

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