

D. High Strength Steel Welding With Yttrium And Fluoride Containing Consumables Effects On Weld Metal Mechanical Properties And Hydrogen Management

by Craig Clasper, Justin Chandler, Stephen Liu, and Glen Edwards, Center for Welding, Joining and Coatings Research

Abstract

The current research was undertaken to study the effects of the addition of fluoride-containing flux ingredients to yttrium-containing consumables on hydrogen management, inclusion formation, microstructure development, and resulting mechanical properties in low alloy steel weld deposits. To study the effects of these flux ingredients on the resulting weld metal microstructures, two series of FCAW consumables were manufactured with different amounts of flux ingredients, and used to produce multiple-pass weld deposits. The weld deposits contained approximately 2.8 wt% Ni, 1.5 wt% Mn, 0.4 wt% Mo, 300 ppm Ti, and 300 to 1000 ppm Y.

The characterization of oxides and microstructures was performed by light optical microscopy. Mechanical properties of these deposits were determined through CVN impact and tensile testing, and microhardness measurements. Welds containing a [%Y]/[%O] ratio between 0.30 and 1.3 resulted in a microstructure that is predominately acicular ferrite, which is expected to result in optimal mechanical properties. The microstructures (flux system without fluoride additions) comprise of 65 to 75 percent acicular ferrite, with the remaining being ferrite with aligned second phases. The oxides present in these welds are spherical and randomly distributed throughout the weld metal. Due to this ratio of Y to O, titanium could combine with oxygen to form oxides, which are known to act as nucleation sites for acicular ferrite. Diffusible hydrogen has been measured to be approximately 2.0 mL H₂/100 g weld metal.

The addition of F-containing flux ingredients to the consumable substantially perturbed the oxygen potential in the weld system and affected the alloying element recovery. The increased oxygen content and reduced alloying content decreased the amount of acicular ferrite to around 50 percent. The presence of increased level of fluoride also affected the stability of the process. Optimization regarding yttrium and fluoride additions must still be done to fully utilize the concepts of hydrogen traps that will render diffusible hydrogen immobile and of removing hydrogen from the arc system by HF formation.

For 100 to 110 ksi (690 to 750 MPa) strength level, the impact toughness came slightly below the requirements imposed by the U.S. Navy: 35 and 60 ft-lb at -60 and 0°F, respectively. Diffusible hydrogen content was around 3.0 mL H₂/ 100g weld metal.