Phase Transformations and Mechanical Properties of Fusion Welds in 10 wt% Nickel Steel

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Background

- High strength 10 wt% Ni steel developed for use by the Navy and other low temperature applications
- It has excellent toughness from mechanically induced transformation of austenite to martensite (i.e., a TRIP steel)
- The austenite is formed during a specialized QLT heat treatment:
  - Three step QLT process is necessary for forming a fine dispersion of stable retained γ in a tempered martensitic matrix
- Dark-field TEM micrographs showing metal carbide precipitates outlining austenite lamellae

Results and Discussion

Autogenous GTAW Results:

- Two distinct morphologies of ICHAZ have been identified, which is unusual
- Microhardness map indicates that hardness of the HAZ is always higher than the BM; highest hardness occurs at ICHAZ 1/ICHAZ 2 boundary
- CGHAZ & FGHAZ: As-quenched lath martensite
- ICHAZ 1: Tempered lath martensite and as-quenched martensite on lath boundaries
- ICHAZ 2: Light and dark etching constituents
- SCHAZ & BM: Tempered lath martensite and coarse autotempered martensite

Gleeble HAZ Simulation Results:

- Regions of high strength and hardness can be correlated with low toughness and retained austenite content
- Low toughness is not solely based on retained austenite as reaustempered by higher toughness in 725°C region
- The thermal cycles associated with the SCHAZ have little effect on the mechanical properties of that region
- The strength trends are consistent with the microhardness trends of the GTAW
- Other peak temperatures (i.e., other HAZ regions) are in progress

Conclusions and Future Work

Summary to Date:

- Results of the autogenous GTAW show that the hardness of the HAZ is higher than the base metal
- Highest hardness in the GTAW occurs at the boundary between the two intercritical microstructures - ICHAZ 1 and ICHAZ 2
- Gleeble HAZ studies indicate that low toughness regions are associated with low retained austenite content and possible carbide formation

Future Work:

- By collaborating with Northwestern University, local electrode atom probe tomography will be used to determine the partitioning behavior of alloying elements between phases
- TEM and modeling using MatCalc software will be used to understand the secondary carbide evolution
- The cause for high strength/reduced toughness in HAZ regions exposed to 725 and 825°C peak temperatures will be established
- Means for restoring HAZ properties will be investigated (e.g., controlled deposition techniques and/or post weld heat treatment)
- Upon conclusion of HAZ studies, research focus will shift to mechanical properties and microstructure evaluation of fusion zone

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Research Objective: Understand how the welding thermal cycles affect phase transformations and mechanical properties in the HAZ of fusion welds of 10wt% Ni steel

- What microhardness trends are observed in an autogenous GTA weld, and how do they correlate to microstructure?
- Can these microstructures be simulated via Gleeble HAZ simulation to allow bulk mechanical property testing?
- Characterization techniques:
  - Light optical and scanning electron microscopy
  - Hardness, tensile, and Charpy impact energy mechanical tests
  - X-ray diffraction to determine retained austenite content
  - Electron backscattered diffraction (EBSD) phase mapping to display the location of retained austenite in the microstructure

Objectives and Approach

- The cause for high strength/reduced toughness in HAZ regions
- Understand how the welding thermal cycles affect phase transformations and mechanical properties in the HAZ of fusion welds of 10wt% Ni steel
- Research focus will shift to mechanical properties and microstructure evaluation of fusion zone