Quarterly Management Report

FY 2007

WBS Element	Project Title	Contract Number	Contract Start	Contract End
	Welding and Corrosion Research: Fe-Al-Cr Weld Overlay Alloys for Ultrasuperficial Coal-Fired Boilers.	4000039738	03/01/05	02/28/08

Performer Name and Address	Principal Investigator(s)
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BUDGET AND COST REPORT

Prior Year Funds [$K]	0
Total Current Year Commitment $K]	300
Projected Current Year Costs [$K]	101

	O	N	D	J	F	M	A	M	J	J	A	S
Planned Costs	6	4	4	4	4	9	5	4	4	45	4	9
Actual Costs	6	2	1	0	0	0	0	0	0	0	0	0
Variance	0	2	3	4	4	9	5	4	4	45	4	9

MILESTONE REPORT

Milestone Designation	Milestone Description	Due Date	Revised Due Date	Completion Date
Task 1	Literature Review	06/15/07		
Task 2	Alloy Design	08/01/07		
Task 3	Hydrogen Thermal Desorption Analysis	10/01/07		
Task 4	Weldability of Alloys	01/31/08		
Task 5	Corrosion Testing	01/31/08		
Task 6	Field Exposure of Alloys	TBD		
Task 7	Final Report Preparation	02/28/08		

TECHNICAL HIGHLIGHTS

A literature review was conducted to find how and why additions to weld metal can reduce the likelihood of hydrogen cracking. It was found that rare-earth and other elements that form oxides and carbides have been added to steels to reduce the amount of hydrogen available to cause embrittlement. These additions act as hydrogen trap sites because they offer an electronic bonding site and / or a stress-field strain-reducing site. Trap sites that have an empty electron bonding orbital at the interface with the matrix atoms are readily bonded by hydrogen atoms. In steels, these sites have been attributed to those formed with elements to the left of Fe in the periodic table, such as Y, Nd, and Ti, which are believed to leave a vacancy in the Fe d-shell. Alternatively, second phases that cause tensile strains in the surrounding matrix lattice offer lower energy sites for hydrogen due to larger inter-atomic spaces. Coherent precipitates tend to have a large attraction for hydrogen trapping due to coherency strains in the lattice. However, coherency strains can be lost at higher temperatures whereupon trapped hydrogen can be released. Electronically bonded hydrogen atoms are less sensitive to changes in temperature.

Yttrium and neodymium based additions have been successfully employed in reducing the diffusible hydrogen content of low-carbon and high strength low-alloy (HSLA) steels. It was found that yttrium oxides and yttrium oxysulfides reduce the susceptibility to hydrogen cracking due to their high binding energy with hydrogen. TiC precipitates have been of research interest in steels due to their high hydrogen binding energies and the ability to control the particle/matrix coherency through heat treatment. Neodymium-based trap sites have been of interest due to their very high binding energy, but low transfer efficiency across the welding arc have been observed. In all cases, increasing fractions of trap sites with high binding energies within a material leads to decreased amounts of hydrogen available for embrittlement.

Research conducted at Lehigh University has shown that a gas-tungsten arc weld (GTAW) overlay composition of Fe - 10wt%Al – 5wt%Cr exhibits good corrosion resistance in simulated low NOx combustion environments. However, implementation of this weld overlay coating in real boiler tube applications requires the use of the gas-metal arc welding (GMAW) process due to its increased deposition rates. Achieving this weld overlay composition without the occurrence of hydrogen-assisted cracking using the GMAW process has proved difficult due to increased incorporation of hydrogen into the weld over GTAW.

The initial objective of this work is to develop a model that will allow the microstructural evolution of Fe-Al-Cr based weld overlays to be controlled by knowledge of the composition. Specifically, by adding controlled amounts of titanium and carbon to the Fe-Al-Cr system, TiC can be formed through a eutectic reaction *in situ* during solidification of a weld overlay. The magnitude of trapped hydrogen will increase with an increased amount of TiC in the microstructure. In order to understand how much TiC will form, the solidification characteristics of the alloy system need to be understood. For instance, the amount of TiC containing eutectic depends on the nominal composition and its relation to the eutectic line. In addition, the solute redistribution behavior of Ti and C in the Fe-Al-Cr system will affect the amount of TiC that remains after solidification. Therefore, liquidus projections were calculated for four alloy systems: Fe – Ti – C, Fe – 5wt%Cr – Ti – C, Fe – 10wt%Al – Ti – C and Fe – 10wt%Al – 5wt%Cr – Ti – C. This was done in an effort to understand the effect of Al and Cr on the formation of TiC. Each alloy system consisted of set Ti and C compositions as follows: (1) 1Ti – 0.1C, (2) 2Ti – 0.1C, (3) 4Ti – 0.1C, (4) 2Ti – 0.2C, all in wt%. These were systematically selected to coincide in each of the four alloy systems for consistency. Preliminary solidification path calculations predicted that the primary phase to form should be ferrite for the range of compositions selected. The formation of a ferrite matrix and a eutectic interdendritic region, comprised of ferrite and TiC, is generally observed in the microstructures, see Figure 1. Preliminary EBSD results confirm that the observed eutectic is comprised of ferrite and TiC within a ferrite matrix.

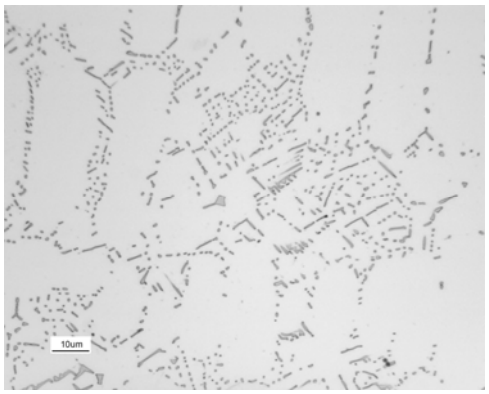

Figure 1: Light optical micrograph showing the microstructure of an arc button melted alloy – Fe – 10wt%Al – 5wt%Cr – 2wt%Ti – 0.2wt%C. The solid colored regions are ferrite and the darker colored particles are TiC in the eutectic interdendritic region.

ISSUES

Report Prepared By	Date
Prof. J.N. DuPont and K.D. Adams	5/22/07