the ENERGY lab

PROJECT FACTS

Advanced Research Materials

Corrosion and Mechanical Properties of Materials in Combustion and Mixed-Gas Environments

Background

A number of advanced technologies are being developed to convert coal to clean fuels for power generation and for use as a feedstock in chemical plants. Coal conversion and combustion processes create by-products that affect the performance of the materials of which the plant components are fabricated, reducing the systems' reliability and efficiency. Contaminants such as alkalis, chlorine, and sulfur vaporize during gasification and combustion. These eventually condense on metal surfaces, causing damage to the protective scale layer on those surfaces. Because of the diverse processing conditions involved in the conversion of coal to gas, a comprehensive understanding of the corrosion behavior of metallic and ceramic materials at high temperatures and pressures in multi-component gas mixtures is essential before practical use of the materials under specified conditions can be considered. The Department of Energy's (DOE) National Energy Technology Laboratory (NETL) is partnering with Argonne National Laboratory to conduct studies to determine the corrosion performance of new and developmental alloys pertinent to advanced steam cycle, oxy-fuel combustion, and enriched/pure oxygen combustion systems.

Project Description

The work being conducted under this project will provide a basic understanding of the protective scale formation mechanisms, the microstructural characteristics of these scales, their sulfur and chlorine resistance, and the causes and mechanisms for scale breakdown in complex gas environments and in the presence of deposits. Experiments will establish the corrosion behavior of several materials that have been developed for advanced steam-cycle application with emphasis on the role of alloy composition in scale development and adhesion, as well as breakaway phenomena leading to scale failure. In particular, the effect of deposits of various chemistries on the corrosion performance of the alloys will be evaluated.

Researchers will compile corrosion data for materials exposed to combustion under enriched-to-pure oxygen and under oxy-fuel conditions. Team members will establish the role of oxidation and carburization of materials in such environments through the assessment of mechanical properties and long-term reliability of various components.

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PARTNERS

None

PROJECT DURATION

Start Date
09/24/2009

End Date
09/30/2011

COST

Total Project Value
$350,000

DOE/Non-DOE Share
$350,000 / $0

Goals and Objectives

The goal of this project is to determine the corrosion performance of new and developmental alloys that are pertinent to advanced fossil-energy power systems. Specific objectives are to evaluate the corrosion performance of materials in simulated combustion environments for application in advanced steam-cycle systems; evaluate the role of deposits containing sulfur and/or chlorine and ash constituents in the corrosion behavior of metallic alloys, selected coatings, and monolithic/composite ceramics; evaluate the residual mechanical properties of materials after exposure in corrosive environments and quantify the effects of corrosion on those properties to enable life prediction of components; and perform corrosion experiments in environments that simulate combustion in enriched oxygen conditions and in carbon dioxide (CO_2) plus steam.

Accomplishments

Researchers completed several corrosion tests to evaluate the corrosion performance of candidate iron (Fe)- and nickel (Ni)-based alloys in pure CO_2, steam, and CO_2-steam environments. Materials selected for the study included intermediate-chromium (Cr) ferritic steels, Fe-Cr-Ni heat-resistant alloys, and Ni-based superalloys. Samples were exposed to pure CO_2 and to CO_2 plus steam environments at temperatures between 650 and 950 degrees Celsius (°C) for up to 10,000 hours. Laboratory tests were also completed in a simulated combustion atmosphere using three deposit chemistries, including ash constituents, alkali sulfates, and sodium chloride. Exposed specimens were examined in detail to evaluate their performance with respect to scaling, internal penetration, corrosion product chemistry, and phases.

Benefits

This project will provide detailed knowledge of the corrosion performance of alloys being considered for use in high-efficiency, low-emissions power plants. The effective design and operation of such power plants will conserve fossil fuels and help to manage global climate change.

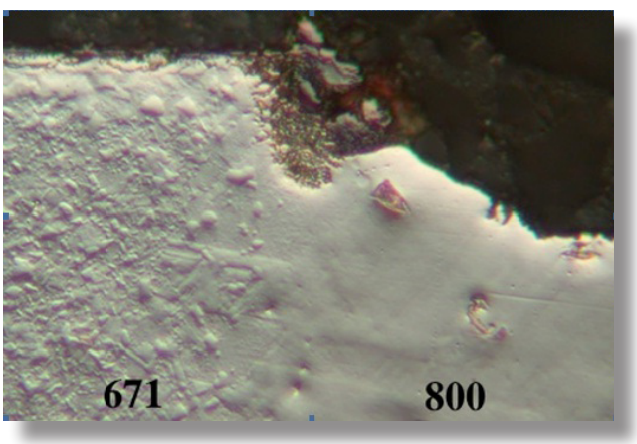

Figure 1. Photomicrograph of a welded sample of alloys 671 and 800 after 668 hours exposure in an environment containing coal-ash at 650 °C.

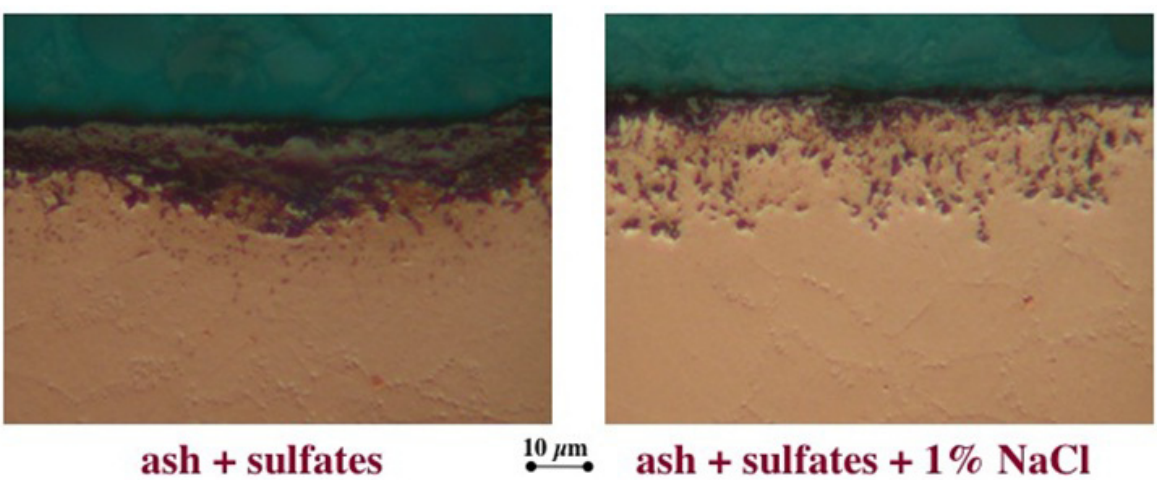

Figure 2. Photomicrographs of alloys 693 after 1680 hours exposure in an environment containing coal-ash and alkali sulfates or alkali chloride at 650 °C.