the ENERGY lab

PROJECT FACTS

Hydrogen Turbines

Preparation and Testing of Corrosion- and Spallation-Resistant Coatings—University of North Dakota

Background

The life of turbine components is a significant issue in gas fired turbine power systems. In this project the University of North Dakota (UND) will advance the maturity of a process capable of bonding oxide-dispersion strengthened alloy coatings onto nickel-based superalloy turbine parts. This will substantially improve the lifetimes and maximum use temperatures of parts with and without thermal barrier coatings (TBCs). This project is laboratory research and development and will be performed by UND at their Energy & Environmental Research Center (EERC) facility and the Department of Mechanical Engineering. Some thermal cycle testing will occur at Siemens Energy (Siemens) in Orlando, FL. UND will also characterize trace fuel contaminants from a pilot-scale gasifier including multiple cleaning processes at EERC to determine more precisely which contaminants are likely to be present in high hydrogen content fuels.

This project was competitively selected under the University Turbine Systems Research (UTSR) Program that permits academic research and student fellowships between participating universities and gas turbine manufacturers. Both are managed by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL). NETL is researching advanced turbine technology with the goal of producing reliable, affordable, and environmentally friendly electric power in response to the nation's increasing energy challenges. With the Hydrogen Turbine Program, NETL is leading the research, development, and demonstration of these technologies to achieve power production from high hydrogen content fuels derived from coal that is clean, efficient, and cost-effective; minimizes carbon dioxide (CO_2) emissions; and will help maintain the nation's leadership in the export of gas turbine equipment.

Project Description

This project is designed to refine the evaporative metal bonding (EMB) method, then apply the refinements to bonding a layer of corrosion- and spallation-resistant alloy (APMT) to turbine parts composed of two nickel superalloy compositions and test the parts to determine if lifetimes have been increased. The work involves measurement of the temperature-dependent diffusion rates of zinc, the bonding metal used in the EMB process. The component superalloys of interest are CM247LC®, and Rene 80. The corrosion and spallation resistant super alloy layer is advanced powder metallurgy techology (APMT). This information will help the EERC-led project team better design the heat treatments needed to create the bonds between the superalloys and the APMT plating and assure that the zinc completely diffuses out of the

CONTACTS

Richard A. Dennis
Technology Manager, Turbines
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4515
richard.dennis@netl.doe.gov

Steven Richardson
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4185
steven.richardson@netl.doe.gov

John P. Hurley
Principal Investigator
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018
701-777-5159
jhurley@undeerc.org

PARTNERS

None

PROJECT DURATION

Start Date	End Date
10/01/2011	09/30/2014

COST

Total Project Value
$600,000

DOE/Non-DOE Share
$480,000/$120,000

AWARD NUMBER

FE0007325

U.S. DEPARTMENT OF ENERGY

turbine components created. The team will also model force distributions in the clamped structures being plated with APMT to assure that the compressive force used to hold the APMT and superalloys together during bonding is adequately distributed over the surfaces being joined. This modeling capability will allow the team to better design the clamping fixtures and force distribution plates (buffers) that will be used to bond plates of the APMT to more complex superalloy turbine parts.

To determine the appropriate conditions for corrosion testing of the bonded parts in simulated turbine conditions, the team will measure trace constituents in combusted syngas produced in the EERC entrained-flow gasifier. This will consist of combusting a slipstream of cleaned coal derived synthesis gas (syngas) produced from the gasifier, quenching the combusted gas with nitrogen, and collecting the submicron particulates on Nuclepore surface filters and gaseous constituents in activated carbon, zeolite traps, or gas impingers. After determining the best heat treatment and clamping methods, the team will bond plates of APMT to the surface of superalloy test samples (buttons) and turbine parts provided by Siemens. Siemens will also apply TBCs to some of the bonded parts and evaluate them. The EERC will perform laboratory hot corrosion tests simulating post-combustor turbine gas compositions, including relevant trace species defined in pilot-scale testing.

Goals and Objectives

The goal of this project is to apply a recently developed method of plating nickel superalloys with protective iron-chromium-aluminum (FeCrAl) layers closer to commercial use in syngas-fired turbines. The project is designed to determine if plating APMT onto nickel-based superalloy turbine parts is a viable method for substantially improving the lifetimes and maximum use temperatures of the parts, both those with TBCs and those without. If successful, the information will help move the protection process close to demonstration testing. In addition, the team will characterize the microcontaminants in combusted higher-hydrogen-content gas. This information will be used to best simulate actual corrosion conditions but can also be used by other researchers studying deposition and gas flow in turbines.

Accomplishments

- All materials, equipment, and clamps assembled for preparation of bonded parts.
- Analysis of the diffusion rates of zinc through the three alloys has been completed at 700 ° and 1214 °C.
- At 700 °C, the diffusivity in APMT is slightly higher (~4 vs. ~2 μm^2/min) than in CM247LC.
- The diffusion rate in the Rene 80 at 700 °C was below UND detection limits.
- The diffusion rate in APMT is approximately 20 times higher than in CM247LC or Rene 80 (~120 vs. ~8 μm^2/min) at 1214 °C.
- The ANSYS finite element model of the clamping system has been completed, including the measured expansion data for the alloys. It is shown in Figure 1.
- A sample calculated stress distribution in APMT at 1214 °C using the present clamping system is shown in Figure 2.

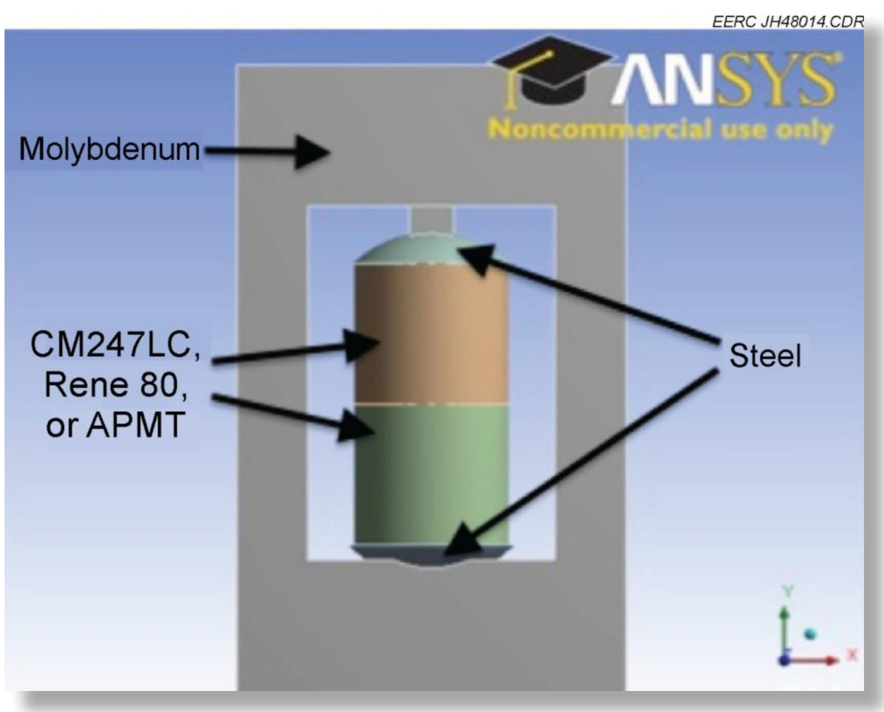

Figure 1. Finite element model used to study stress distributions during bonding.

- Sampling of vapor and particulate matter present in filtered syngas created in pilot-scale gasification systems continues.
- The particles collected after the system warm-gas filter are typically 0.2 to 0.5 μm in diameter, as shown in Figure 3.
- After the syngas is combusted, the particles appear slightly larger and much more spherical, as shown in Figure 4.

Benefits

This UTSR project supports DOE's Hydrogen Turbine Program that is striving to show that gas turbines can operate on coal-based hydrogen fuels, increase combined cycle efficiency by three to five percentage points over baseline, and reduce emissions. This work will advance the method of plating nickel superalloys with protective FeCrAl layers toward commercial use in syngas-fired turbines and will greatly increase the lifetimes and maximum-use temperatures of nickel superalloy turbine components.

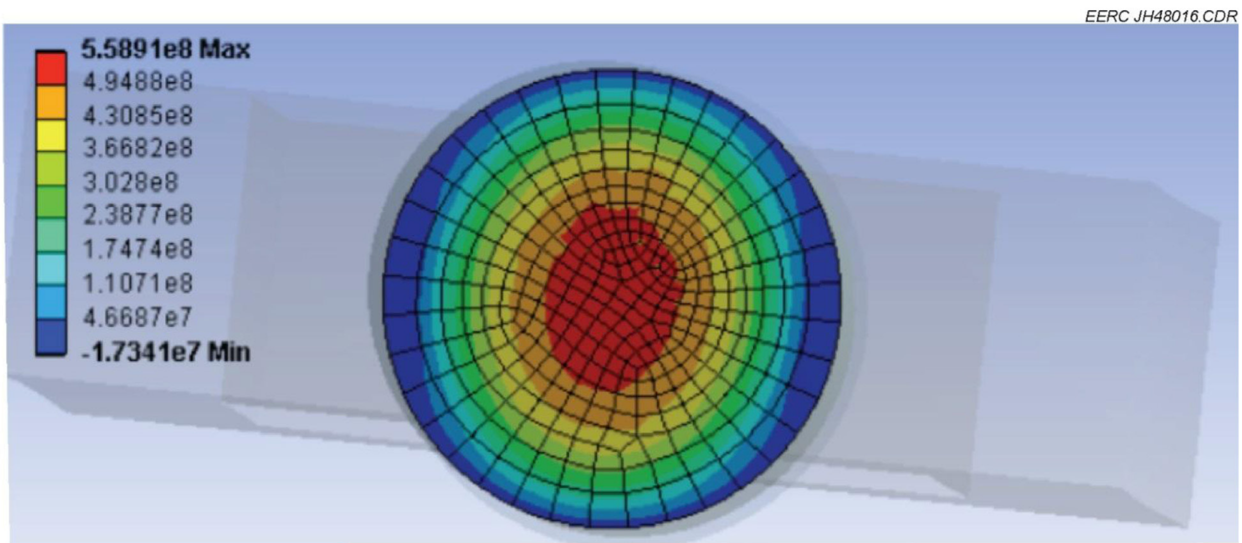

Figure 2. Normal stress distribution at bonding interface during bonding of APMT at 1214 °C.

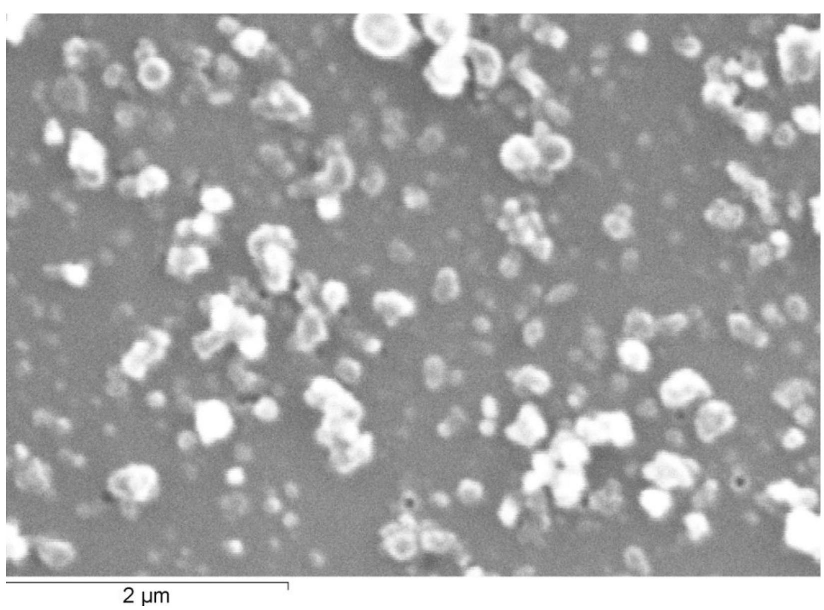

Figure 3. Particles collected at the thermal oxidizer inlet from scrubbed and filtered syngas.

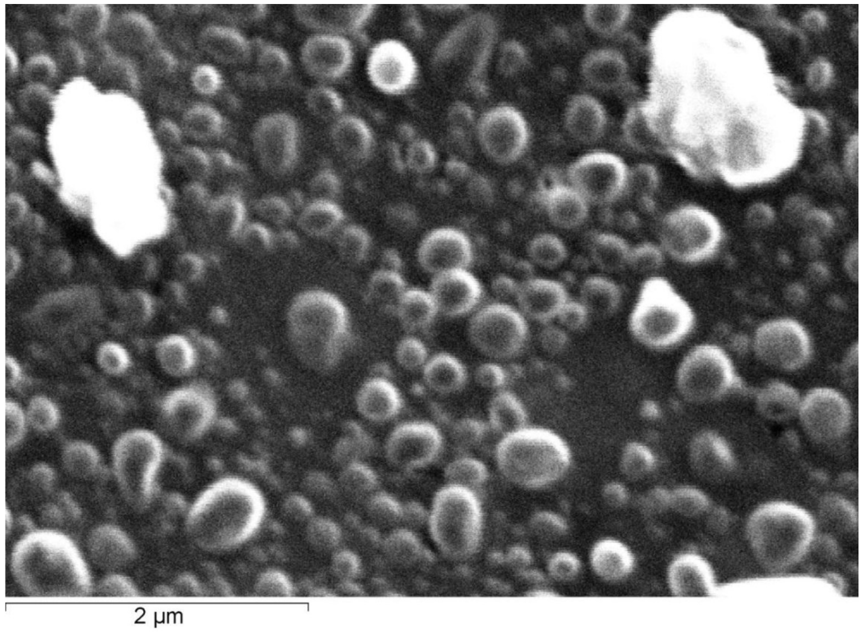

Figure 4. Particles collected from the thermal oxidizer outlet after burning syngas that had been filtered and scrubbed.