Materials

ORNL Partners with Industry for Testing of Ceramics and EBCs

Keiser Rigs Evaluate Long-Term Stability of Materials in High Temperature and High Pressure Environments

Background

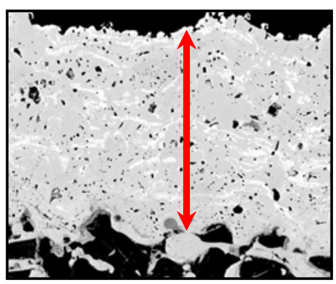
The use of Si-based ceramic materials in gas turbine and microturbine engines components is problematic due to their recession in high temperature, H_2O-containing environments. Surface recession of these ceramics in water vapor occurs by oxidation to form surface SiO_2 and subsequent volatilization of the SiO_2 as $Si(OH)_4$ in the high gas-velocities in turbine engines. Volatilization (surface recession) is the life-limiting factor for Si-based ceramics, and an environmental barrier coating (EBC) will be necessary to protect the gas-path surface. EBCs protect the ceramic substrate by creating a permeation barrier to oxidizing species (oxygen and water vapor) and exhibiting volatilization resistance.

ORNL's high-temperature, high-pressure exposure furnace -"The Keiser Rig"

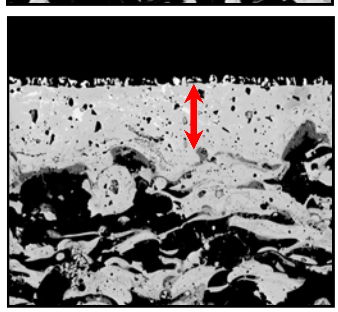
Technology

ORNL Keiser Rigs allow exposure of ceramic materials and candidate EBCs to simulated combustion environments (high water-vapor pressures) for very long times (>5000 h); post-exposure characterization provides an invaluable means by which to interpret and understand the exposure data.

The Keiser Rigs have been used during the past few years to quantify the recession rates of uncoated SiC-based continuous-fiber ceramic composites (CFCC) and Si_3N_4 materials using simulated gas turbine and microturbine environments. Conditions with high temperatures, high water-vapor pressure, but slow-flow gas velocities are employed to evaluate the permeation-resistance of many potential EBC compositions. Initial screenings of EBCs were conducted in a Keiser Rig at water-vapor pressures typically found in turbine engines (0.3–2.0 atm). More recently, very high H_2O pressures (~20 atm)



Original BSAS-based EBC top coat thickness ~200 µm.



Final EBC top coat thickness after ~14,000 h engine-test < 60 µm. Thickness loss due to recession of BSAS surface.

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have been utilized to evaluate EBC volatility. High water vapor pressure compensates for the slow-flow velocities in the Keiser Rig, and such exposures will be used to provide low-cost volatility screening of EBCs in water vapor.

Numerous collaborations have developed as a result of the ORNL research on water-vapor effects, and ceramic material exposures in the Keiser Rig have been extensive. As of September 2004, a total of more than 650,000 ceramic specimen hours have been accumulated in the ORNL Keiser Rigs.

SiC-SiC CFCCs	**GE Power Systems Composites** **Goodrich Corporation**
Oxide-Oxide CFCCs	**ATK-COI Ceramics, Incorporated**
Si_3N_4 and Sialon	**Honeywell Ceramic Components** **Saint Gobain Ceramics & Plastics** **Kyocera** **Kennametal**
Environmental Barrier Changes	**United Technologies Research Center** **ATK-COI Ceramics, Incorporated** **SMAHT Ceramics**
Gas Turbine and Microturbine Engines	**Solar Turbines, Incorporated** **General Electric Siemens Westinghouse**

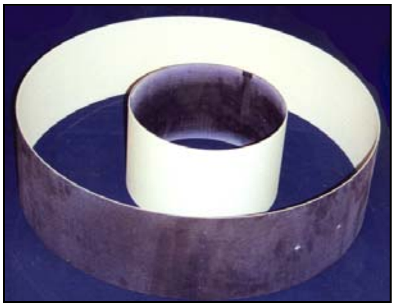
Benefits

There are numerous benefits for using ceramic materials for hot section components in gas turbine and microturbine engines; however, it has been demonstrated that Si-based ceramics will not survive long-term exposures in gas turbine and microturbine combustion environments. Rapid surface recession of these materials is life-limiting, which necessitates the use of protective EBCs. ORNL Keiser Rigs can be used to initially screen candidate EBCs for permeation- and volatilization-resistance prior to exposing the EBCs to significantly more expensive engine tests.

Long-term exposures of several SiC-based CFCCs and candidate EBC compositions in the Keiser Rig have resulted in the down-selection of materials to those with the best long-term stability potential in H_2O-containing environments. Combustor liners were produced from a SiC-SiC CFCC and a BSAS-based EBC based on Keiser Rig exposure data and were run in Solar Turbines Centaur 50S engines at the Chevron engine test site in Bakersfield, CA and the Malden Mills engine test site in Lawrenceville, MA for ~14,000 h at each site.

Future Work

Low-cost volatilization assessment of candidate EBCs will continue. Exposure data will also be used to develop a complete understanding of the role of water vapor on the permeation- and volatility-resistance of different EBCs. Many of the results will be compared with similar material exposures conducted in actual engine tests.



CFCC combustor liners with EBC on gas-path surfaces

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