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Bruce Pint
Materials Science and Technology Division, ORNL

Kinga Unocic
Materials Science and Technology Division, ORNL

Michael Lance
Materials Science and Technology Division, ORNL

J. Allen Haynes
Materials Science and Technology Division, ORNL

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Bruce A. Pint, Materials Science and Technology Division, ORNL
pintba@ornl.gov
Kinga A. Unocic, Materials Science and Technology Division, ORNL
Michael J. Lance, Materials Science and Technology Division, ORNL
J. Allen Haynes, Materials Science and Technology Division, ORNL

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While the water vapor content of the combustion gas in natural gas-fired land based turbines is ~10%, it can be 20-85% with coal-derived (syngas or H_2) fuels or innovative turbine concepts for more efficient carbon capture. Additional concepts envisage working fluids with high CO_2 contents to facilitate carbon capture and sequestration. Also, for land-based, power-generation turbines, there is industry interest in reducing alloy costs by decreasing the superalloy Re content, either by developing new alloys or employing earlier generation superalloys. To investigate the effects of these variables on thermal barrier coating (TBC) lifetime, furnace cycling tests (1h cycles) were performed in air with 10, 50 and 90 vol.% water vapor, O_2-50%H_2O and CO_2-10%H_2O and compared to prior results in dry air or O_2. Two types of TBC's were investigated: (1) diffusion bond coatings (Pt diffusion or simple or Pt-modified aluminide) with commercially vapor-deposited yttria-stabilized zirconia (YSZ) top coatings on second-generation superalloy N5 and N515 (1.5%Re) substrates and (2) high velocity oxygen fuel (HVOF) sprayed MCrAlYHfSi bond coatings with air-plasma sprayed YSZ top coatings on superalloy X4, 1483 and 247 substrates. For both types of coatings, a 20-50% decrease in coating lifetime was observed with the addition of water vapor for all but the Pt diffusion coatings which were unaffected by the environment. However, the higher water vapor contents in air did not further decrease the coating lifetime. Initial results for similar diffusion bond coatings in CO_2-10%H_2O also did not show a decrease in lifetime due to the addition of CO_2. Characterization of the failed coating microstructures showed only minor effects of water vapor and CO_2 additions that do not appear to account for the changes in lifetimes observed. Reductions in TBC lifetime were observed for 1483 substrates (compared to X4), which were attributed to the lower Al content and possible the higher Ti content. The higher Hf content in N515 (compared to N5) likely explains the higher TBC lifetimes observed for this substrate. More recent work with 247 substrates is in progress as well as furnace testing with 100h cycles to better simulate the base load duty cycle. Future work also is planned to investigate the role of SO_2 on TBC lifetime as increased water vapor contents in the exhaust do not explain the current 50°-100°C de-rating of syngas-fired turbines.

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