Investigation of Materials in High Moisture Environments Including Corrosive Contaminants Typical of Those Arising by Using Alternate Fuels in Gas Turbines

Fact Sheet

I. PROJECT PARTICIPANTS

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II. PROJECT DESCRIPTION

A. Objectives

- Develop a fundamental understanding of the degradation processes in moisture environments and in such environments where the specimens have deposits which are typical of deposits that will be encountered from the use of alternate fuels.
- Attempt to describe how moisture/contaminant levels and temperature affect the corrosion processes.
- Determine the alloy compositions and coatings that are most resistant to corrosion induced by deposits from alternate fuels.
- Compare the degradation of a ceramic matrix composite (CMC) and a state-of-the-art TBC under conditions typical of gas turbines using conventional fuels and in environments containing water vapor and contaminants representative of turbines using alternate fuels.

A. Background/Relevancy

Background: When gas turbines use alternate fuels, ash from the fuels can deposit on turbine hardware. This deposited ash can cause substantial corrosion of turbine hardware which may have significantly different characteristics than Type I or Type II hot corrosion. This research is directed

at investigating and understanding the corrosion of materials induced by ash deposits typical of those that are formed upon use of alternate fuels. The added complication of high moisture environments is also considered.

Relevancy: Much of the previous materials development for power generating gas turbines has been performed with natural gas as the fuel of choice. More recently, the need for fuel flexibility has caused alternate fuels such as syngas to be considered for use in gas turbines. Preliminary testing with a variety of alternative fuels has shown increased deposition of ash, as well as highly aggressive corrosion of turbine materials that was more severe in the presence of moisture. This research is relevant since it is directed at investigating the corrosion induced by ash deposition and moisture from use of alternative fuels. The alloys and coatings to be studied are typical of those used in current power generating gas turbines, as well as those that may be used in advanced systems.

B. Period of Performance

August 1, 2004-July 31, 2007

C. Project Summary

Under the University Turbine Research (UTSR) program, the University of Pittsburgh is investigating the effects of deposits and moisture on the high temperature degradation of alloys and coatings typical of those being used in current power generating gas turbines, as well as those that may be used in advanced systems. This project consists of six tasks (see Figure 1) which are discussed in the following:

Task I: Selection and Preparation of Alloys and Coatings to be Studied in This Program

The alloys being studied are GTD 111, René N5, and IN 738. These three alloys are being examined without coatings, as well as with NiCrAlY, CoNiCrAlY, and platinum modified aluminide coatings.

Task II: Selection of Test Conditions

In order to compare the degradation of the alloys and coatings under relevant test conditions, but using a reasonable number of tests, a limited number of coated alloys were exposed to cyclic oxidation tests using deposits of Na_2SO_4, CaO, and $CaSO_4$. These tests were performed at temperatures of 750°, 950°, and 1150°C in dry and wet (P_{H2O}=0.1atm) air. Based upon the results obtained in this task, it was decided to use the following test conditions in comparing the degradation of all of the alloys and coatings: Cyclic oxidation (45 minutes hot zone, 15 minutes cold zone) at 950°C, compare specimens with and without deposits of CaO (0.5-1.0 mg/cm^2) in dry and wet air.

Task III: Comparison of Alloys and Coatings Using Test Conditions Described in Task II

The results obtained in the cyclic oxidation of the three alloys without any coatings show some important features. When CaO deposits are not present, René N5 oxidizes significantly slower than GTD 111 and IN 738. This occurs because René N5 is an Al_2O_3-former whereas GTD 111 and IN 738 are Cr_2O_3-formers. When water vapor is present in the gas environment the oxidation is not much different than in dry air, but the internal oxidation appears to occur along alloy grain boundaries in the two polycrystalline alloys. CaO deposits in dry air cause all three alloys to exhibit more degradation, but this attack is more severe on René N5 compared to GTD 111 and IN 738. The addition of water vapor to the gases causes the attack induced by CaO

deposits to be more severe for all three alloys because there is more cracking and spalling of oxide in wet air. Again the degradation of René N5 is more severe than that of GTD 111 and IN 738.

Tests are in progress to compare the degradation of the three alloys with coatings of NiCrAlY, CoNiCrAlY, and a platinum modified aluminide.

Task IV: Determine Moisture/Contaminant Limits

The purpose of this task is to determine the effects of contaminant amount and water vapor partial pressure. It has been found that CaO deposits cause increased degradation of all of the systems studied. Moreover, more attack occurs as the amount of CaO deposited is increased. The influence of water vapor pressure on this CaO-induced degradation is currently being investigated.

Tasks V and VI

These two tasks involve tests using TBCs (Task V) and a CMC (Task VI) to investigate the effects of CaO-induced attack on such systems in dry and wet air at 950^{o}C. Specimens for such tests are currently being processed and testing of these specimens will be performed in the third year of this program.

III. PROJECT COSTS

$340,206.00

IV. MAJOR ACCOMPLISHMENTS SINCE BEGINNING OF PROJECT

- Specimens of IN 738, René N5, and GTD 111 with coatings of CoNiCrAlY, NiCrAlY, and a platinum modified aluminide have been fabricated.
- Test conditions representative of those conditions that may be encountered upon using alternate fuels have been developed to compare the alloys and coatings.
- The alloy René N5 has been found to degrade more rapidly when subjected to CaO deposits than IN 738 and GTD 111.
- The attack of alloys induced by CaO deposits becomes more severe as the amount of this deposit is increased.

V. MAJOR ACTIVITIES PLANNED DURING THE NEXT 6 MONTHS

- During the next six months, tests will be performed at 950^{o}C with CaO deposits to compare the degradation in wet and dry air of IN 738, GTD 111, and René N5 with CoNiCrAlY, NiCrAlY, and platinum modified aluminide coatings.
- Experiments will be performed to determine the influence of water vapor pressure on CaO-induced attack of some of the alloys and coatings being studied in this program.

VI. MAJOR ACCOMPLISHMENTS PLANNED IN OUTYEARS (6 MONTHS)

- Fabricate TBC and CMC specimens.
- Test the TBC and CMC specimens at 950^{o}C in the presence of CaO deposits in dry and wet air.

VII. ISSUES

- None

VIII. ATTACHMENTS

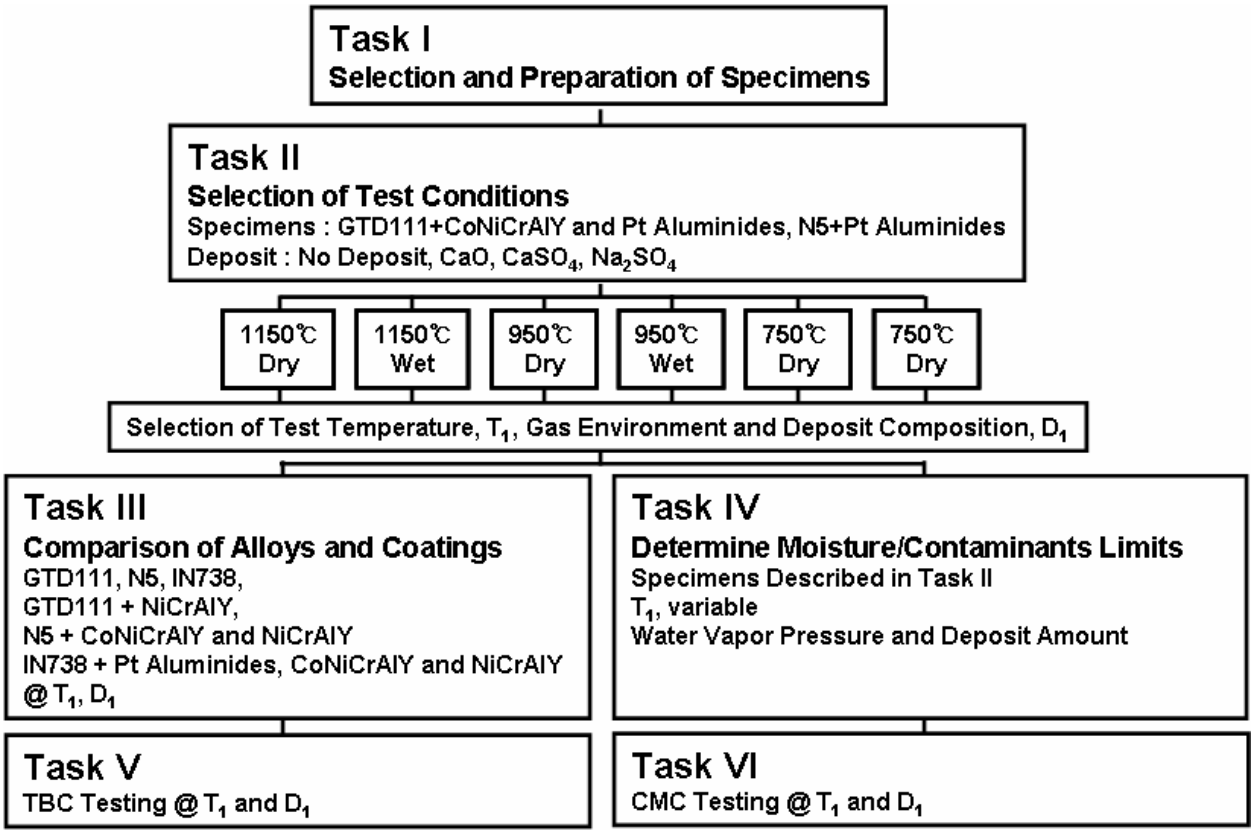

Figure 1. Schematic flow diagram for the present program.