N89-12883

HOST SURFACE PROTECTION R&T OVERVIEW

Robert A. Miller
NASA Lewis Research Center
Cleveland, Ohio

Most of the efforts in the HOST Surface Protection Subproject were focused on thermal barrier coating (TBC) life prediction in fiscal year 1986 (fig. 1). Also, small effort - consisting primarily of wrapping up and reporting the work of previous years - remained on the airfoil deposition modeling. The metallic coating life prediction program, which had been an element in the surface protection subprogram in previous years, was not continued into FY 1986.

The TBC life prediction element is divided into contractural, grant, and in-house efforts (fig. 2). The contracts - with Pratt & Whitney Aircraft, General Electric Co., and the Garrett Turbine Engine Co. - were designed to produce "engine-capable" TBC life-prediction models. The grant with Cleveland State University is focused on finite-element modeling of TBC stress states. The in-house work is focused primarily on developing laboratory burner rig tests that can simulate the pressures and heat fluxes of aircraft gas-turbine engines.

AIRFOIL DEPOSITION MODEL

The work performed under the airfoil deposition modeling program element in FY 1986 is outlined in figure 3. This effort was concerned with modeling the deposition of corrodants onto turbine airfoils. Accomplishments included verification of the chemically frozen boundary (CFBL) theory, which had been developed in previous years at Yale University under HOST and other NASA programs. Encouraging results were also received with the recently developed local thermochemical equilibrium (LTCE) theory.

THERMAL-BARRIER-COATING LIFE PREDICTION

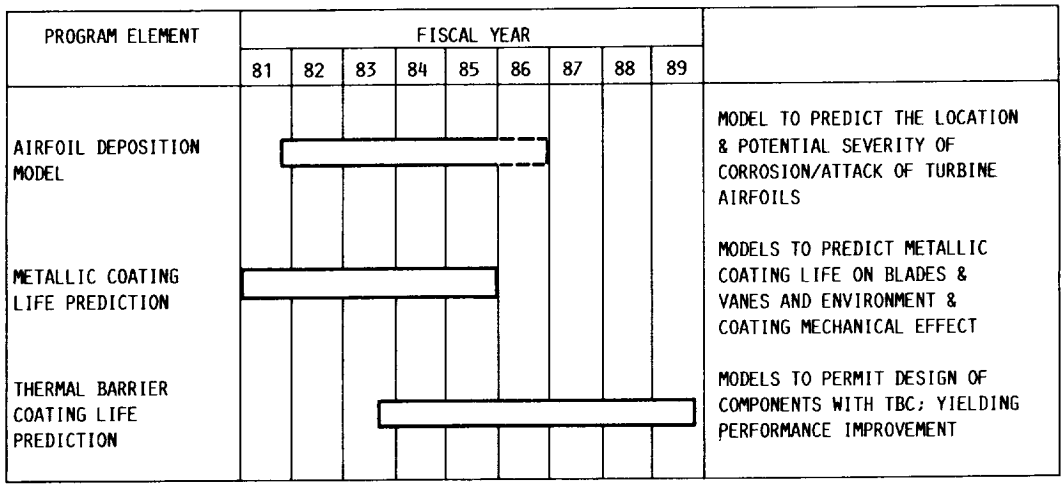
Most of the FY 1986 surface protection subprogram was devoted to thermal-barrier-coating life modeling. This modeling is an essential step in the development of TBC's. This is because the full benefits of TBC's can only be achieved when it becomes possible to use them in the "prime-reliant" mode. An uncoated airfoil cannot survive the temperatures that are encountered in this environment. Therefore, a failed TBC would lead directly to a failed component. As noted in figure 4 TBC life prediction models combined with other advances in coatings technology will be required before designers will be willing to use TBC's in the prime reliant mode.

Figure 5 shows that the TBC life modeling contracts are divided into two phases. Currently, each of the three contractors is in the third and final year of phase I. The output of phase I will be a preliminary model. The output of the second phase will be a design-capable model. The modeling strategy is indicated in figure 6. Figure 5 also shows how the mechanical behavior of TBC's program is focused on the modeling of TBC residual stresses. The in-house rig/engine

correlation work is aimed at high pressure burner rig development as is shown in figures 5 and 7.

TBC HOST FY 1986 accomplishments are shown in figure 8. These include the development and initial verification of a preliminary life model by one of the contractors (Pratt & Whitney Aircraft). Coating mechanical and thermal properties have been determined. Failure mechanisms have been ellucidated. Stresses have been modeled by finite-element methods. Also, NDE methods have been evaluated, and an engine test has been conducted (by the Garrett Turbine Engine Co.).

SURFACE PROTECTION



CD-86-21503

Figure 1

SURFACE PROTECTION

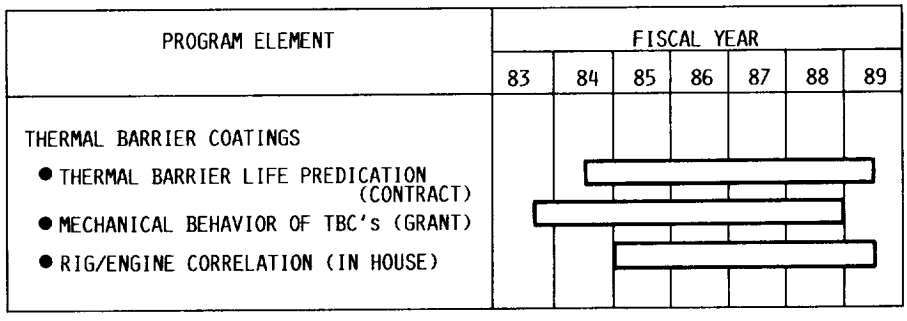


Figure 2

CD-86-21498

AIRFOIL DEPOSITION MODEL

GOAL:
- TO DEVELOP AND VERIFY A MODEL TO PREDICT CORRODANT DEPOSITION QUANTITY AND LOCATION ON TURBINE AIRFOILS

APPROACH:
- AIRFOIL MODEL DEVELOPMENT VIA GRANT WITH DAN ROSNER, YALE
- MODEL VERIFICATION VIA IN HOUSE RESEARCH WITH SUPPORT FROM GOKOGLU
  - MACH 0.3 BURNER RIG
  - HIGH PRESSURE BURNER RIG
- BURNER RIG MODERNIZATION
  - COMPUTER DATA ACQUISITION AND LIMIT MONITORING
  - COMPUTER CONTROL

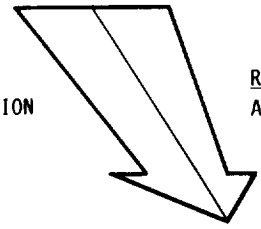
STATUS:
- CFBL THEORY VERIFIED FOR SEGMENTED COLLECTORS SIMULATING TURBINE NOSE REGION
- LTCE THEORY, RECENTLY DEVELOPED, WHICH ASSUMES LOCAL THERMOCHEMICAL EQUILIBRIUM AS OPPOSED TO FROZEN CHEMISTRY (CFBL THEORY), AGREES TO WITHIN 7% IN PREDICTING DEPOSITION RATES
- PUBLICATIONS IN PROGRESS

CD-86-21496

Figure 3

STRONG HOST SUPPORT VITAL TO TBC PROGRESS

NOW: TBC's USED AS ADD-ONS;
INADEQUATE DESIGN CAPABILITY



HOST
TBC LIFE PREDICTION

R&T BASE PROGRAMS
ADVANCED COATINGS

FUTURE: PRIME RELIANT TBC's FOR USE ON AIRFOILS FOR BIG PERFORMANCE IMPROVEMENT

Figure 4

CD-86-21501

THERMAL BARRIER COATING LIFE PREDICTION

GOAL:
- TO DEVELOP AND VERIFY LIFE PREDICTION METHODOLOGIES FOR (TBC's)

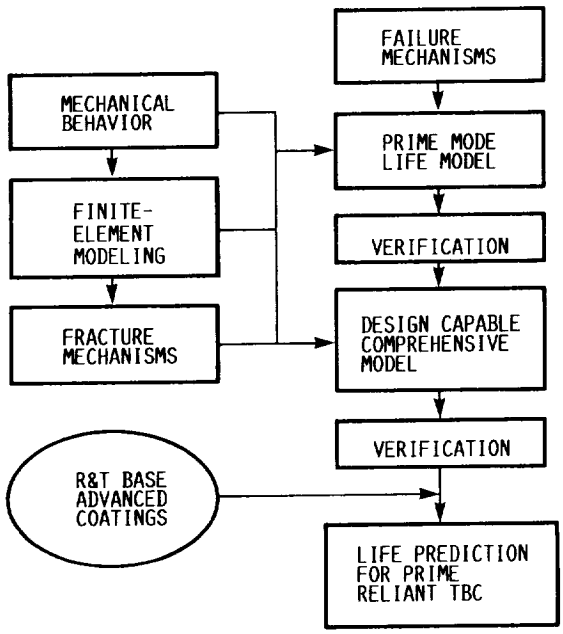
APPROACH:
- TBC LIFE PREDICTION MODEL DEVELOPMENTS (CONTRACT)
  - PHASE I: FAILURE ANALYSIS AND PRELIMINARY MODEL (MULTIPLE CONTRACTS)
  - PHASE II: DESIGN CAPABLE MODELS (TBD)
- MECHANICAL BEHAVIOR OF TBC (GRANT, CSU)
  - RESIDUAL STRESS MODELING
- RIG AND ENGINE CORRELATION (IN-HOUSE)
  - HIGH-HEAT FLUX TESTS IN HIGH-PRESSURE BURNER RIG TO COMPLEMENT CONTRACT EFFORT
  - FAILURE MECHANISMS
  - MODEL VERIFICATION
  - COMPLEMENTARY PROGRAMS

STATUS:
- PRELIMINARY LIFE MODEL UNDER DEVELOPMENT

CD-86-21497

Figure 5

THERMAL-BARRIER-COATING LIFE PREDICTION



CD-86-21500

Figure 6

RIG/ENGINE CORRELATION

GOAL:
- PROVIDE A UNIQUE AND RELATIVELY INEXPENSIVE LABORATORY TO AID IN THE DEVELOPMENT OF ENVIRONMENT ATTACK LIFE PREDICTION TOOLS FOR HOT SECTION MATERIALS

APPROACH:
- VERIFY ADVANCES MADE IN THE LIFE PREDICTION OF HOT-SECTION MATERIALS AT PRESSURE LEVELS ENCOUNTERED IN GAS-TURBINE ENGINES

STATUS:
- RIG OPERATIONAL
- LIMITED TESTING PLANNED FOR MID 1987

CD-86-21499

Figure 7

HOST FY86 TBC ACCOMPLISHMENTS

- PRELIMINARY LIFE MODEL DEVELOPED (PWA)
- COATING MECHANICAL AND THERMAL PROPERTIES DETERMINED
- FAILURE MECHANISMS ELLUICIDATED
- STRESSES MODELLED BY FINITE ELEMENT ANALYSES
- NDE METHODS EVALUATED (GTEC)
- ENGINE TEST CONDUCTED (GTEC)

CD-86-21502

Figure 8