Design Concepts for Cooled Ceramic Matrix Composite Turbine Vanes

To reduce emissions and improve fuel consumption in gas turbine engines

This project demonstrated that higher temperature capabilities of ceramic matrix composites (CMCs) can be used to reduce emissions and improve fuel consumption in gas turbine engines. The work involved closely coupling aerothermal and structural analyses for the first-stage vane of a high-pressure turbine (HPT). These vanes are actively cooled, typically using film cooling. Ceramic materials have structural and thermal properties different from conventional metals used for the first-stage HPT vane. This project identified vane configurations that satisfy CMC structural strength and life constraints while maintaining vane aerodynamic efficiency and reducing vane cooling to improve engine performance and reduce emissions. The project examined modifications to vane internal configurations to achieve the desired objectives. Thermal and pressure stresses are equally important, and both were analyzed using an ANSYS® structural analysis. Three-dimensional fluid and heat transfer analyses were used to determine vane aerodynamic performance and heat load distributions.

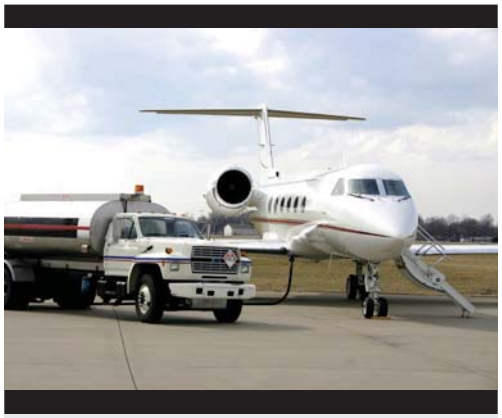
Applications

NASA

- Gas turbine engine applications:
  - Develop new materials to increase turbine inlet temperatures
  - Reduce vane cooling to lower combustor outlet temperature without decreasing rotor inlet temperature
  - Reduce specific fuel consumption and carbon dioxide (CO_2) emissions

Commercial/Military

- Transport aircraft:
  - Improve specific fuel consumption in gas turbine engines
- Power:
  - Reduce fuel consumption and CO_2 emissions of gas turbines



Phase II Objectives

- Perform aerothermal analyses for the first-stage vane of the high-pressure turbine of the energy-efficient engine (EEE)
- Identify benefits of reduced specific fuel consumption and nitric oxide emissions due to CMC vanes and blades
- Evaluate thickness, hoop, and radial component stresses for EEE vane
- Evaluate stresses due to pressure, thermal, and combined loads
- Evaluate significance of film cooling holes on stresses
- Evaluate stresses due to the presence of trailing-edge ejection cooling tubes
- Evaluate sensitivity of component stresses to variations in material properties and boundary conditions
- Evaluate radial cooling concepts for small engine application

Benefit

- Reduces emissions and improves fuel consumption in gas turbine engines

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