Life Predictions for Gas Turbine Components

The NRC Institute for Aerospace Research (NRC Aerospace) has the personnel, expertise and facilities to successfully predict the life of gas turbine critical components, such as blades, vanes, discs, spacers and cooling plates. Key technological capabilities include:

- thermomechanical stress and fracture mechanics analysis
- representative material data and data generation
- life prediction algorithms
- non-destructive evaluation (NDE) with ability to generate probability of detection (POD) data, and
- coupon and component level life validation testing.

NRC Aerospace staff have the expertise to effectively solve realistic life prediction problems. We provide services related to the structural integrity, durability and reliability of gas turbine engine structures and components, in addition to ongoing life prediction R&D activities.

The Institute offers finite element-based stress and fracture mechanics analyses, as well as testing services ranging from coupon and component level to full-scale engine testing. Its unique expertise and comprehensive facilities are available to evaluate and qualify both new and repaired engine materials and structures.

To ensure that the client's objectives are met in the most cost-effective way, structural analyses, material testing or life prediction algorithms are customized to their needs. All research and life prediction services are available through collaborative research or fee-for-service contracts.

Stress and fracture mechanics analysis capabilities

- State-of-the-art computational facilities with extensive graphic capabilities
- FEM commercial software: MSC.NASTRAN, MSC.PATRAN, MSC.MARC, ABAQUS, in addition to inhouse-generated software to create finite element models for stress, strain, thermal and fracture mechanics analysis of gas turbine engine components
- State-of-the-art experimental strain analysis techniques including reflection photoelasticity to measure shear strains, digital image correlation to measure strain and surface deformation, shadow/projection moire capabilities as well as advanced strain gauge equipment.

Material testing capabilities

- Stress and strain amplitude-controlled low cycle fatigue (LCF) and thermomechanical fatigue testing (up to 1100°C and 98 kN in air)
- Creep and stress rupture testing (up to 1100°C in air)
- Fatigue and creep crack growth rates testing with direct or alternating-current potential drop (DC-PD, AC-PD) or compliance crack growth monitoring capabilities.

NDE capabilities for aircraft engine components

- Eddy current techniques, consisting of manual as well as fully automated systems for crack detection/sizing in bolt-holes, dove-tails and other critical locations as well as for oxides detection in thermal barrier coatings
- Pulsed thermography for detection of debonding in thermal barrier coatings
- Liquid penetrant and magnetic particle inspections for a variety of gas turbine applications
- Radiography, including micro-focused real-time x-rays for locating inclusions, voids, porosity, corrosion and cracks as well as blockage of air channels in turbine blades
- Ultrasonic methods using conventional longitudinal or shear waves as well as guided waves and leaky waves for flaw detection and thickness gauging

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- Electrical impedance and conductivity measurements for material sorting and coating inspections
- Enhanced optical surface inspection techniques including the Edge-of-Light method for detection of wear and surface flaws
- Boroscope, video microscope and replication apparatus for viewing internal or external surfaces
- Portable instruments and variety of probes and manual scanning devices for in-situ inspections
- Multi-mode NDI Analysis software for presentation, analysis and interpretation of inspection signals/images from a variety of techniques
- Probability of detection (POD) and confidence analysis for determination of safe inspection intervals.

Life prediction algorithms

NRC Aerospace has adopted the physics-based holistic life prediction philosophy, which considers that a component's total life consumption consists of crack nucleation and crack growth. Microstructural damage mechanisms, including dislocation pile kinetics, slip irreversibility and grain boundary sliding under thermomechanical conditions, are taken into account. Failure mechanisms of coating systems, such as thermal barrier coatings, are also considered in life prediction where applicable.

For damage tolerance characterization NRC Aerospace uses state-of-the-art fracture mechanics-based life prediction algorithms for gas turbine components. Safe Inspection Intervals (SII) can be determined for a client's specific gas turbine usage and non-destructive evaluation capability. NRC Aerospace can also predict creep and low cycle fatigue life of hot section components.

Life validation testing services

- Spin rig testing of gas turbine components and other rotating component assemblies to validate predicted life. Performance, strength, durability and damage-tolerance tests can be carried out under cyclic, steady-state, or combined loads, at room or elevated temperatures. Programmable for cycle mission simulation with rotational speed up to 100,000 rpm
- High velocity burner rigs that can simulate engine gas path conditions for thermal fatigue testing of hot section components and coatings
- Blade HCF testing can be done using an electrodynamic shaker with frequencies up to 2500 Hz
- Engine test cells and auxiliary equipment for turbo-jet and turbo-shaft engines are also available.

Track record

The latest projects include:

- SII predictions for J85 and Nene-X discs, Nene-X impeller, and T56 wheels and spacers
- creep life prediction for IN738LC blades
- fatigue life prediction for single crystal Ni-base superalloys
- life prediction of plasma-sprayed thermal barrier coatings for turbine blades
- life prediction of titanium alloys under thermo-mechanical loading and dwell condition.

CONTACT:

Dr. Prakash Patnaik
Structures & Materials Performance Laboratory
NRC Institute for Aerospace Research
Ottawa, Ontario, Canada K1A 0R6
Tel: (613) 991-6915 Fax: (613) 990-7444
E-mail: prakash.patnaik@nrc.gc.ca

Mr. Jeff Mackwood
Marketing and Contracts Office
NRC Institute for Aerospace Research
Ottawa, Ontario, Canada K1A 0R6
Tel: (613) 990-0765 Fax: (613) 952-7214
E mail: jeff.mackwood@nrc.gc.ca

Or visit our Web site at: www.nrcaerospace.com

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