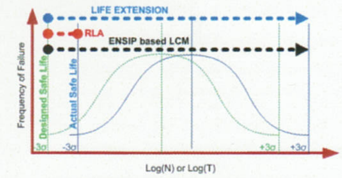
Engine Specific XactLIFE™ GT V1.0

Damage Tolerance Assessment Service using ENSIP and XactLIFE™

Patented Technology: CA 2604118/20, US 8,116,990 B2

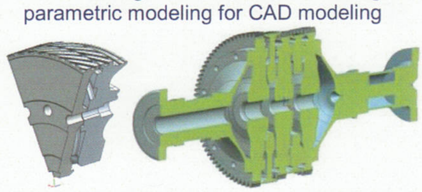
LIFE Prediction Technologies inc.

- Rotor Life Extension is not a Residual Life Assessment (RLA) problem but a Life Cycle Management (LCM) problem based on the actual usage loads of the specific engine being analyzed
- MIL-HDBK-1783B ENSIP based LCM of the turbine rotors follows a three stage process including :
  - Qualitative metallurgical analysis and quantitative fracture critical location determination
  - Fracture Mechanics based Damage Tolerance Analysis and a Safe Inspection Interval (SII) Prediction
  - Life Extension of Rotor Assembly using Risk Analysis for a missed flaw distribution and material variability



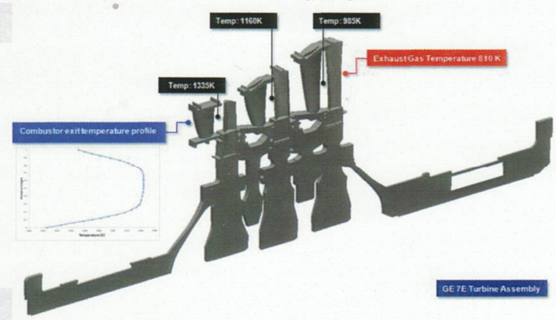
Reverse Engineering, CAD Modeling

- Reverse engineering the components
- Point cloud generation, model cleaning and parametric modeling for CAD modeling



Engine Modeling and Analysis

- On-design engine condition used for calibrating the thermodynamic models for Off Design Engine Modeling (ODEM)
- ODEM performed on Client's base load to obtain accurate boundary conditions for CFD
- Mean line parameters such as temperature, pressure, mass flow computed for actual engine usage

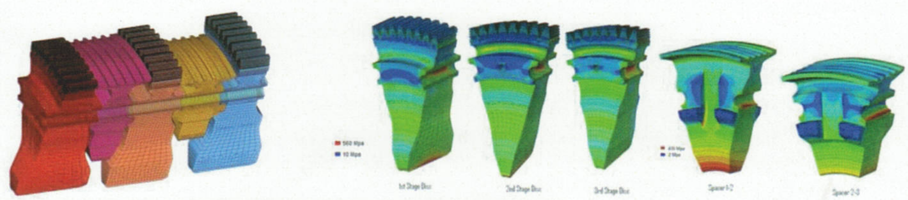


CFD (Cascade and CHT) Analysis

- Cascade analysis for the entire hot gas path to obtain accurate boundary conditions for stage-wise CFD analysis
- Model cleaning and high quality CFD mesh generation
- Conjugate Heat Transfer (CHT) analysis of bladed disk models for each stage
- Temperature prediction over the entire rotor assembly under service loads

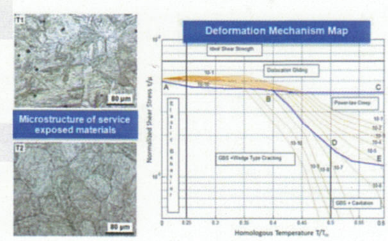
Coupled Structural Analysis

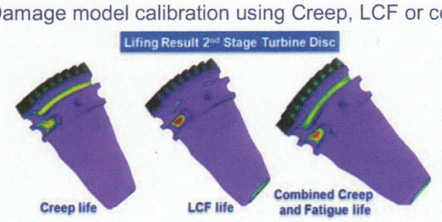
- High quality structured mesh generation
- Stage wise FEA based on realistic boundary conditions derived from actual loading, assembly information and CFD temperature profiles
- Temperature dependent material with isotropic as well as orthotropic (DS) definitions for blades



Microstructure and Deformation Mechanism based Damage Modeling

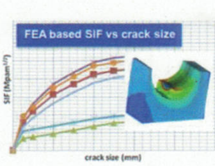
- Microstructure parameters are collected for the component material and used in the damage models
- Deformation mechanism map used for the selection of appropriate damage models under actual usage loads
- Damage model calibration using Creep, LCF or combined loading generated as per ASTM guidelines

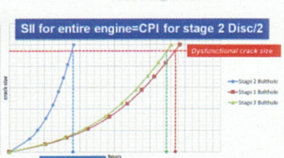




Fracture Critical Location Identification

- Nodal stress-strain-temperature states used in damage models - Creep, LCF and combined creep-fatigue to identify fracture critical locations (FCL) with lowest life
- Component divided into 8 regions and 8 FCL identified



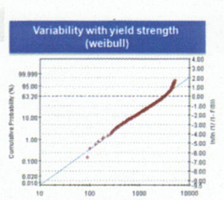


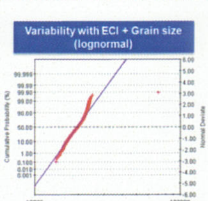
Damage Tolerance Analysis and Safe Inspection Interval

- MIL-HDBK-1783B Engine Structural Integrity Program (ENSIP) guidelines followed for DTA
- 90/95 Probability of Detection assumed for the initial crack size missed during inspection
- Dominant Fracture Mechanics parameter of SIF change computed with crack block enabled FEA as a function of crack size and loading at the primary and secondary FCLs
- Safe Inspection Interval (SII) calculated based on half the duration/cycles required for the initial crack to propagate to a dysfunction size, for the worst case scenario
- Lowest SII for the identified FCL of all components is selected for LCM of the rotor assembly

Probabilistic Analysis

- Reliability of SII based on probabilistic calculations using inspection and material variability
- Acceptable cumulative Probability of Failure (PoF) of 1 in 1000 to a dysfunctional crack size is selected as the criterion





Summary

- ENSIP process followed for the entire design life expired rotor assembly
- Physics based Prognostics used to establish fracture critical locations, Fracture Mechanics based DTA used to calculate SII
- Based on analysis, the design life expired rotors can continue to be used in service with updated analysis
- The reliability of the SII is established using ENSIP guidelines
- An inspection guide is created for the Clients

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