Compact Gas Turbine Sub-Project

TC 4.2 Compact, High Overall Pressure Ratio (OPR 50+) Gas Generator

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Compact GT Subproject

Future propulsion systems will be of increasingly higher bypass ratio from larger fans combined with much smaller cores

AATT TC 4.2 Compact, High Overall Pressure Ratio (OPR 50+) Gas Generator
Enable reduced size/flow high pressure compressors and high 1500F temperature disk/seals for gas generators with 50+ OPR with minimal impact on noise and component life (TRL4)

Technical Challenge Investments
- Hot Section Materials (incl: Hybrid Disk & High Temp Seals)
- Reduced Size/Flow HPC Technologies & Concept(s) Development

Emerging TC Investments
- Adaptive Fan Blade (incl Shape Memory Alloy & Toughened Fan Blade)
- Active Tip Clearance Control: Planning Effort with go/no-go start in FY16

TC4.2(FY19): Compact, High Overall Pressure Ratio (OPR 50+) Gas Generator, TRL 4

Objective

Aero | Struc | **Prop** | Clean | Quiet

Develop critical technologies to enable reduced size/flow gas generators with 50+ OPR and disk/seal temperatures of 1500F with minimal impact on noise and component life (TRL4).

Technical Areas and Approaches

Hot Section Materials

- 1500F disk & coatings
- 1500F capable non-contacting seal

High Pressure Compressor Technologies

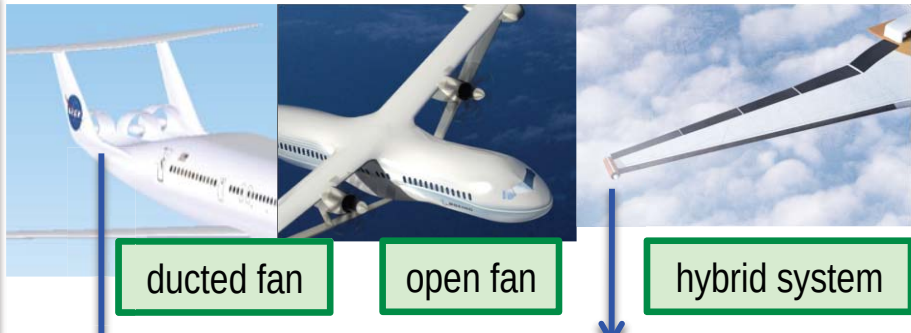
- **P&W NRA:** system study, compressor design to mitigate losses, design/fab/testing, casing treatment if needed
- **GE NRA:** system study, existing N+3 relevant compressor hardware, low/high speed tests of casing treatment with large tip gap blading

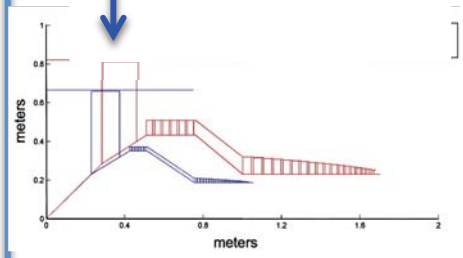
High Pressure Turbine Technologies

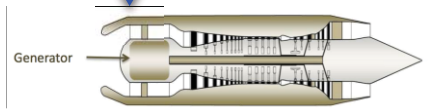
- Developing plan

Benefit/Pay-off

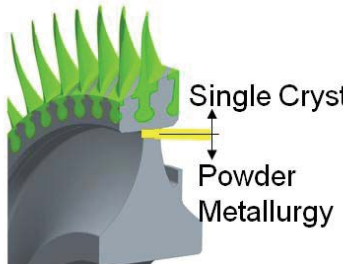
- Advanced compact gas-generator core architecture and component technologies enabling BPR 20+ growth by minimizing core size
- Thermally efficient, high OPR (50+)



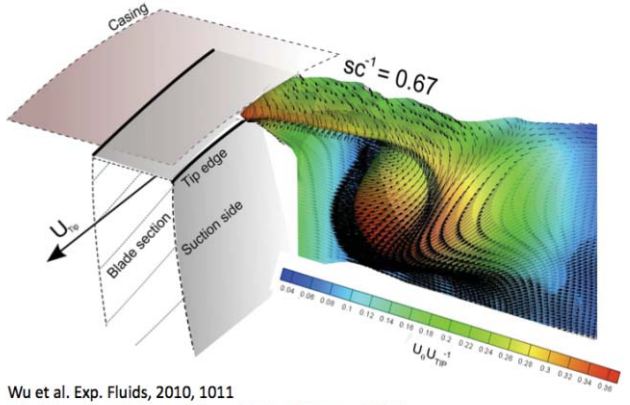




materials, aerodynamics, and control



1500 F, bonded hybrid disk concept



Wu et al. Exp. Fluids, 2010, 1011
Miorini et al., J. Turbomachinery 2012, AIAA Journal 2012

Tip/endwall aerodynamic loss mitigation

TC 4.2: Disk Alloy Coatings To Mitigate Hot Corrosion

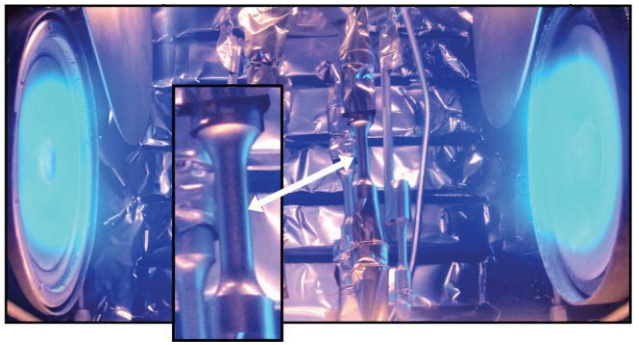
Problem
Higher disk operating temperatures lead to oxidation and hot corrosion -- strongly degrading low cycle fatigue (LCF) life.

Objective
Develop oxidation/hot corrosion resistant coatings that maintain most of uncoated LCF life.

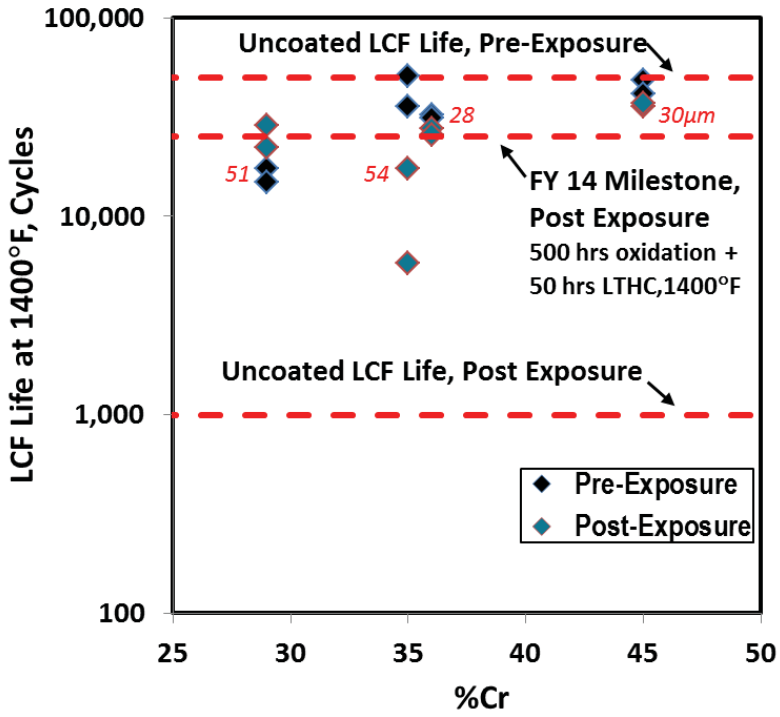
Approach
Apply high chromium coatings, initially by sputtering, onto disk-alloy LCF test bars. Compare lives before and after exposure: oxidation and low temperature hot corrosion (LTHC) at 1400°

Results
- Disk alloy bars coated with Ni-45%Cr-Y (1mil thickness, peened, pre-oxidized, exposed to oxidation and LTHC) maintained over 70% of the fatigue life of baseline samples (uncoated).
- Reducing the coating flaws via substrate surface modification and high impulse sputtering will be the next steps in producing an environmentally protective coating.

Significance
High %Cr coatings greatly improve the performance of disk alloys after oxidation and LTHC, and is a key technology for disk alloy material concepts to enable High OPR (40+) gas generator core for fuel burn benefits. Paths to further improvements identified.



Fatigue Bars in plasma enhanced magnetron sputtering (PEMS) coater at vendor



Higher Cr coating retain over 50% of uncoated/ unexposed LCF life after 500 hrs oxidation/ 50 hrs LTHC at 1400°F

Research Team: Robert Miller, Tim Gabb, Jack Telesman, Sue Draper, & Chantal Sudbrack (GRC, LMA)

TC 4.2: Small Core Size Design Challenge for High OPR Engine

Problem

Enable high OPR (40+) gas generator core for improved thermal efficiency and fuel burn reduction

Objective

Mitigate aerodynamic losses and resulting decrements in high OPR core compressor and turbine efficiencies due to larger tip clearance and under-platform seal cavity gaps associated with small core size.

Approach

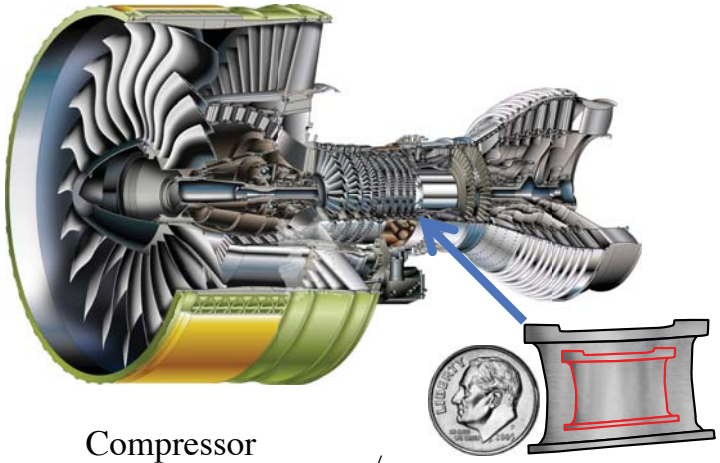
Solicit NRA proposals for N+3 relevant system studies of high OPR core to assess benefits and develop concepts, approaches, and roadmaps to substantiate potential performance and fuel burn benefits of proposed technologies, and then down-select most promising concept(s) for TRL 4 testing.

Results

NRAs awarded to GE for an advanced casing treatment concept applied to an advanced HPC aft block, and to P&W for a conceptual and preliminary design of a HPC tied to N+3 relevant system studies, followed by low and high speed tests of candidate blade design and technology concepts in a scaled HPC aft block commensurate with manufacturing limitations of small core blade.

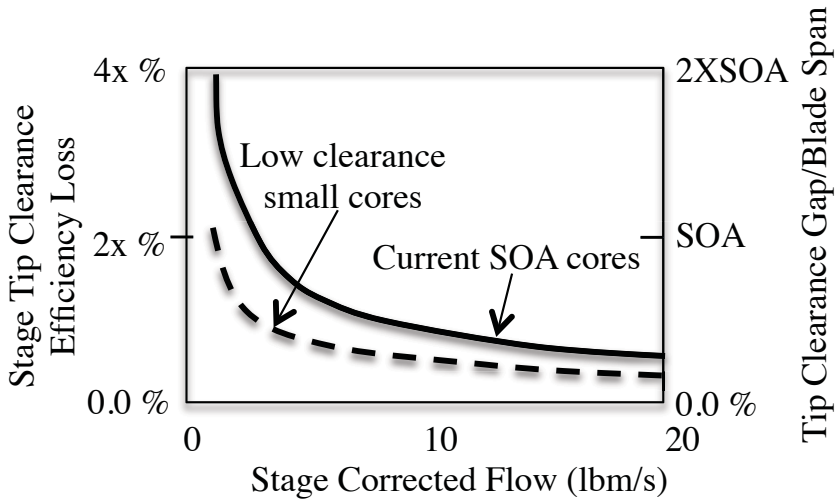
Significance

TRL 4 demonstration of benefits afforded by high OPR small core engine concept anchored by N+3 relevant system studies.



Compressor exit corrected flow "core size" $\frac{W\sqrt{\theta}}{\delta}$

6.0 lbm/s vs. 2.0 lbm/s core size



Research team: Chunill Hah (COTR, P&W NRA, NASA GRC) , Vikram Shyam (COTR, GE NRA, NASA GRC)

FY14 Progress and Accomplishments

- Completed hybrid disk coating studies (GRC)
- Second round hybrid turbine disk linear friction weld trials demonstrated significant bond improvement; no porosity, no secondary phase and no Al2O3 particle contamination at the bond interface (GRC)
- Conducted room temperature static and bind-up tests of a baseline non-contacting finger seal GRC)
- Conducted in-house and funded work to define potential high efficiency small core architectures (GRC)
- Prepared a report examining historical development of technology affecting gas turbine engine fuel economy (GRC)
- Completed Particle Image Velocimetry and Focused Schlieren tests of long hole film cooling resulting in comprehensive benchmark data set for CFD validation (GRC)
- Assessed aerodynamic impact of shaped film cooling holes on a PW HPT blade (under SAA) including flowfield, film effectiveness, and boundary layer measurements (GRC)
- Showed significant improvement to composite damage tolerance using the thermoplastic interleave approach for toughened composite blade (GRC)
- Developed finite element modeling methodology for analysis and failure predictions of adhesively bonded joints of shape memory alloy (SMA) ribbon and polymer matrix composite (PMC) substrates system structures for adaptive composite fan blade shape change concept (GRC)
- All turbomachinery tip clearance/endwall loss NRA's requested short no-cost extensions to complete experiments and documentation (NRA's)