DEVELOPMENT OF HIGH MISALIGNMENT CARBON SEALS

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The Ultra Efficient Engine Technology (UEET) program is a NASA-funded program to develop and demonstrate technology for quiet, fuel-efficient, low-emissions next generation commercial gas turbine engines.

An essential role for achieving lower noise levels and higher fuel efficiency is played by the power transmission gear system connected to the fan.

Geared systems driving the fan will be subjected to inertia and gyroscopic forces resulting in extremely high angular and radial misalignments.

Because of the high misalignment levels, compartment seals capable of accommodating angularities and eccentricities are required. Pratt & Whitney and Stein Seal Company selected the segmented circumferential carbon seal as the best candidate seal type to operate at highly misaligned conditions and developed a test program to determine misalignment limits of current segmented circumferential seals. The long-term goal is to determine a seal design able to withstand the required misalignment levels and provide design guidelines.

A technical approach is presented, including design modification to a "baseline" seal, carbon grade selection, test rig configuration, test plan and data acquisition. Near term research plans and back-up seal designs are also presented.

Development of High Misalignment Carbon Seals

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High Misalignment Carbon Seals

Background

Tomorrow's Engines with geared fans will be subjected to extreme conditions such as:

High angular and radial seal misalignments

Gyroscopic loads - angular misalignment

Sun input gear orbiting - radial/eccentric misalignment

Seals capable of accommodating high misalignment and low pressure differentials must be developed.

Background information on principal causes of extreme conditions in Advanced Commercial Engines. Such conditions impose on seals high misalignment, high rubbing speed, large diameters and low pressure differentials.

High Misalignment Carbon Seals

Objectives:

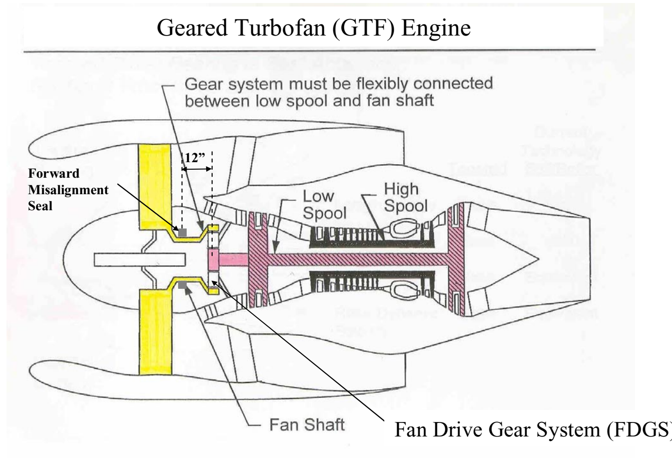
- Determine misalignment capabilities of existing circumferential segmented seals and develop design(s) to meet requirements.
- Enabling technology for Geared Turbofan (GTF) Engine.

Other industry applications benefiting from new seal technology

- F119 - Circumferential segmented seal employed
- High misalignment seal applications
- Other aircraft engine manufacturers will see improved background in today's misalignment and low pressure differentials seal capabilities.

Overview of FY '00 objectives: start development of the high misalignment seal with baseline testing. Other possible industry beneficiaries of improved seal technology are also listed.

High Misalignment Carbon Seals



Sketch of Geared Turbo Fan position and connection to the rest of the engine. Input shaft to GTF is connected to LPC shaft and the GTF output shaft is connected to the fan shaft.

High Misalignment Carbon Seals

	FWD. AIR/OIL SEAL	REAR AIR/OIL SEAL
Required Life (hours)	30,000	30,000
Delta P (psi)	<50	<50
Surface Speed (ft/s)	50	129
Buffer Air Temperature (deg. F)	350	350
Angular Misalignment (deg)	0.5	0.2
Eccentricity (inches)	0.005	0.02
Sealing Diameter (inches)	2.95	2.95
Type	Segmented/ bellows/ other	Segmented/ other

Seal Operating Conditions

Seal operating conditions (required life, pressure differentials, speeds, misalignment levels and others).

Critical requirements are highlighted.

High Misalignment Carbon Seals

Seal Selection

- **Types Considered**
  - Segmented circumferential
  - Face
  - Bellows
- **Considerations**
  - Seal mass
    - Must operate with high inertia loads
  - Strength
    - Ability to survive potential high impact loads
  - Flexibility
    - Conformance to rotating surface and misalignment

This slide describes seal selection.

Only contact seals were considered.

High Misalignment Carbon Seals

Segmented Circumferential Seal Chosen

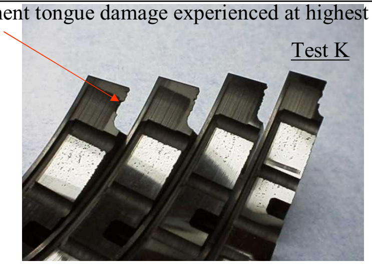
- Low seal mass
  - Small cross-section made of lightweight carbon material
- Conformability to shaft / misalignment
  - Segmented design allows better tracking
- Simple design
  - No secondary seal

This slide discusses selection of the segmented circumferential seal. Historically face seals have large sections, thus greater mass. A face type seal requires a secondary device which could complicate operation at high misalignment.

High Misalignment Carbon Seals

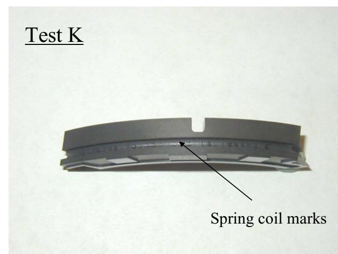
Segment tongue damage experienced at highest angularities

Chipped carbon segments after 0.5° ang. misal. test



Similar damage after combined misal. test

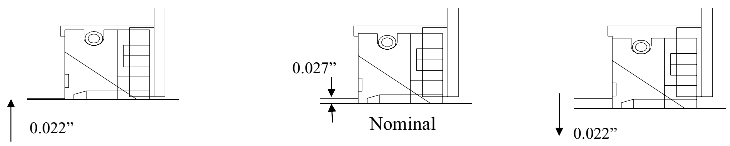
Test J - Seal runner after test. Similar in test K



Seal runner after test K, similar after test J

High Misalignment Carbon Seals

Baseline Seal



Normal design practice

- 0.027 max. radial clearance between housing & shaft.
- Max radial movement 0.022

This slide discusses the baseline seal for this program and lists its advantages and disadvantages. The seal has a longer than normal tongue and socket but is within current design practice.

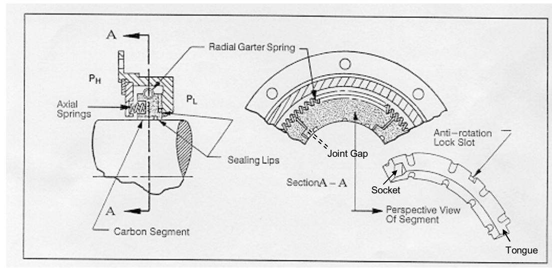
High Misalignment Carbon Seals

To meet future design requirements the following concerns must be addressed:

- Joint wear
- Lock slot wear from contact with anti-rotation pin
- Extension (garter) spring movement
- Compression spring movement

Issues too complex to resolve.

Alternate design needed to meet overall goals



This slide discusses the effect of trying to use current design practice for large shaft misalignments. There are too many concerns that are difficult to address and the configuration is not being considered.

High Misalignment Carbon Seals

Information to be used for alternate design:

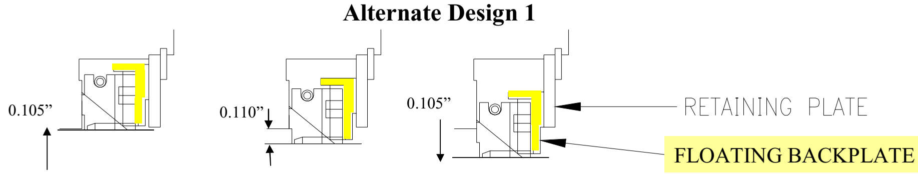
- Tests have shown higher angularities damage segment tongues
  Problem can be fixed with tongue re-design
- Carbon wear to be addressed in alternate design concepts

Where do we go from here:

- Complete 0.040” radial offset test
  - More data/experience for designing/developing alternate design
- With added info, design and develop 2 concepts:
  1) Floating backplate
  2) Floating backplate and bushing

High Misalignment Carbon Seals

Alternate Design 1



•**New design concept** – Floating backplate up to a .110 radial clearance
•Eliminates joint, lock slot, spring movement concerns

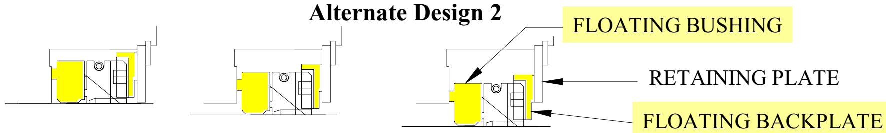
•**Must look at:**
•Anti-rotation of floating backplate
•Friction between plates
•Face and bore dams must be increased
•Material for plates

ADVANTAGES	**DISADVANTAGES**
•Normal tongue and socket joint •Normal tongue and socket gap •Minimal joint wear •Minimal lock slot and key wear	•High garter spring load •Complex, unproven backplate design •More costly •Larger face and bore dam widths •Higher heat generation

This slide describes the design to be used for radial clearances above .040”. To minimize inertia effects, light weight materials for the floating backplate will be evaluated. Hardenable material or hard coated surfaces will be considered to reduce friction between the floating backplate and retaining plate.

High Misalignment Carbon Seals

Alternate Design 2



- **New design concept** – Floating backplate and floating bushing up to a .110 radial clearance between housing & shaft.
- Max radial movement to be .105
- Allows for near normal segmented seal design
- **Must look at:**
- Anti-rotation of floating backplate
- Friction between plates
- Material for bushing and plates

ADVANTAGES	DISADVANTAGES
•Normal seal ring design	•Complex design
•Normal garter spring design	•Backplate design unproven
•Normal tongue and socket joint	•More costly
•Normal tongue and socket gaps	•Ceramic floating bushing
•Minimal joint wear	•Floating bushing unproven in aerospace applications
•Normal size face and bore dam widths	•Requires more space than other designs
•Less bore wear and heat generation	
•Minimal lock slot and key wear	

This slide describes an alternative design for the large clearances in this application. Addition of the floating bushing allows the segmented seal to operate as a normal clearance device. Stein has used floating bushings in industrial applications.

High Misalignment Carbon Seals

CONCLUSIONS

- Established limits of baseline circumferential segmented seal. 0.5° angularity and 0.010” eccentricity achievable with modified baseline seal.
- 0.5 deg tests damaged segment tongue. Tongue re-design can eliminate problem.

Air Leakage

- Higher air leakage occurred at higher angularity tests.
- Air leakage increased linearly with ΔP.
- Little effect of speed on air leakage.

Oil Weepage

- Very low throughout all testing.

Wear

- Angularity tests produced higher radial wear.

Recommendations

- New design needed to reach overall goal of 0.5° angularity and 0.105” eccentricity.
- Test modified baseline seal at 0.040” eccentricity. Use data to design / develop 2 alternate concepts.
- Develop and test floating backplate designs.