ADVANCED BEARINGS/SEALS FOR GENERAL AVIATION ENGINES

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Objectives

Global

Develop Seal, design tools and manufacturing technology
To support NASA, GAP, and Aerospace Industries

Specifically

- Develop preliminary bearings/seals for W.I.GA engine
- Enhance/Expand existing compliant foil, and analysis tools for seals
- Select materials and coatings (commercialization of NASA PS 304 coatings
- Validate analysis through experiments

Compliant Foil Seals

Needs

Consistent function at high temperature and pressure
Wear resistance
Compact & Lightweight

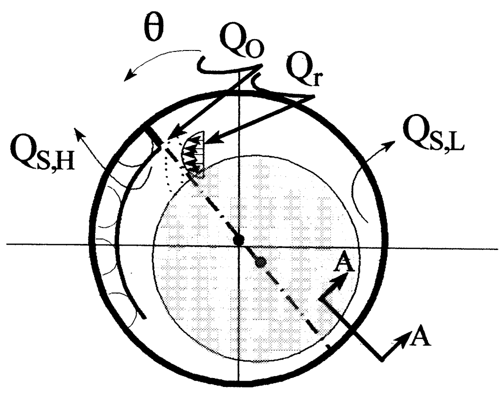
Materials

High Temperature Foil Inco X-750
High Temperature Shaft Coating - NASA PS304

Special Considerations

Thermal Analysis: temperature not to exceed material capabilities
Flow Analysis - Coupled hydrodynamic and compliancy

A Simplified Model for Flow & Thermal Effects in a Foil Bearing



Side Flow

$Q_S \approx Q_{S,L} + Q_{S,H}$

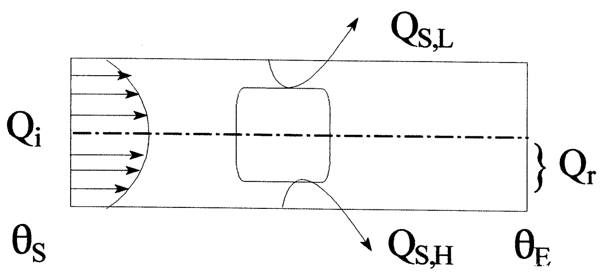
Inlet

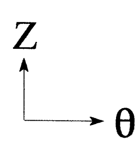
$Q_i \approx Q_O + Q_r$

$T_i = f(T_O, T_r)$

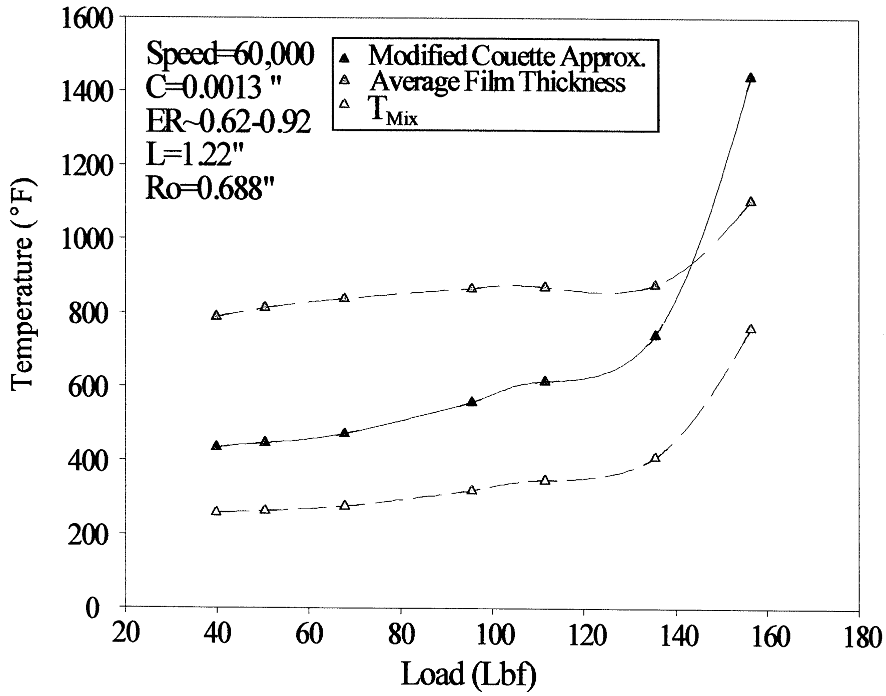
Energy Balance Approximation

$Q_i T_i \approx Q_S T_{S,avg} + Q_r T_{max,avg}$

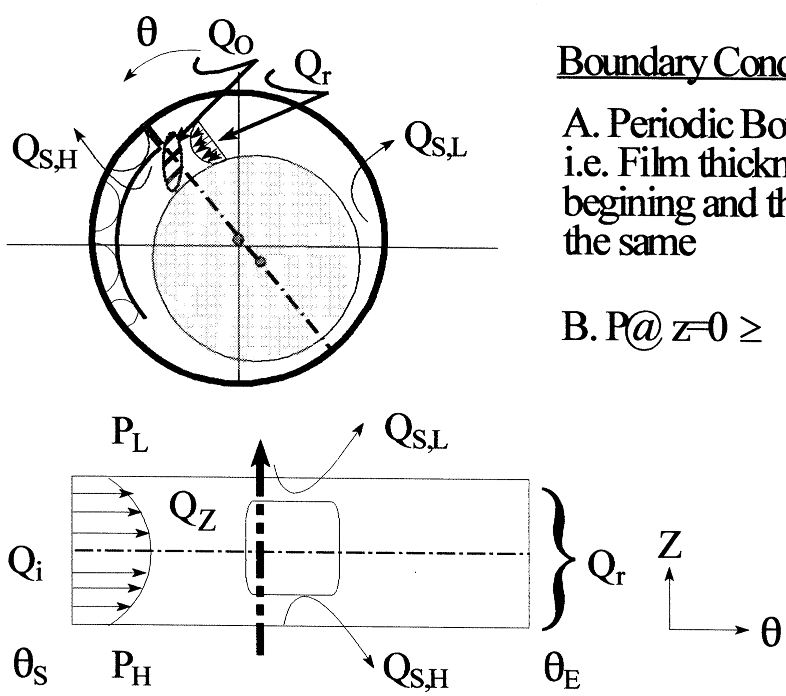




Approximate Temperatures from the Analysis of Foil Bearing



Flow Model in a Seal



<u>Boundary Conditions:</u>

A. Periodic Boundary @ θ_S and θ_E i.e. Film thickness and presure at the begining and the end of the seal are the same

B. P@ z=0 ≥ P@z=L

Governing Equations and Boundary Conditions

Reynolds Equation:

Velocity & Inertia

$$\frac{\partial}{\partial\theta}\left[\bar{P}\,\bar{h}^{3}\frac{\partial\bar{p}}{\partial\theta}\right]+\frac{\partial}{\partial\bar{z}}\left[\bar{P}\,\bar{h}^{3}\frac{\partial\bar{p}}{\partial z}\right]=\Lambda\frac{\partial}{\partial\theta}(\bar{P}\,\bar{h})$$

$\bar{z} = (Z/R)$ $\bar{p} = (P/P_L)$ $\bar{h} = (h/C)$

Film Thickness :

Compliancy

$$\mathbf{h = C + e\,Cos\,(\theta - \theta_0) + \sum K_{ij}\,(p_{eff} - PN)}$$

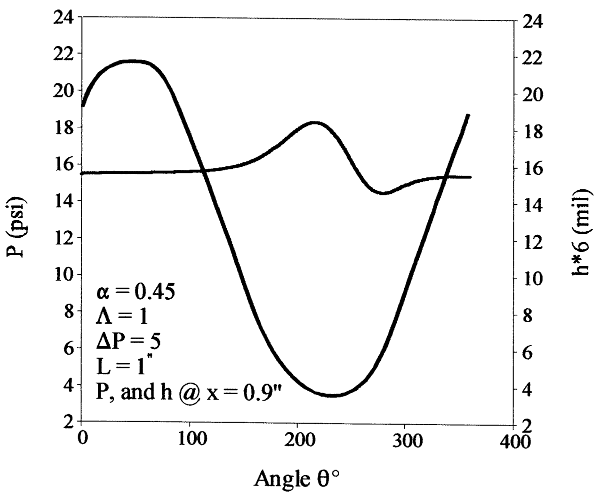
K_{ij} : The combined compliancy coefficeint
PN: Normalized pressure behind foils

Numerical Approach:

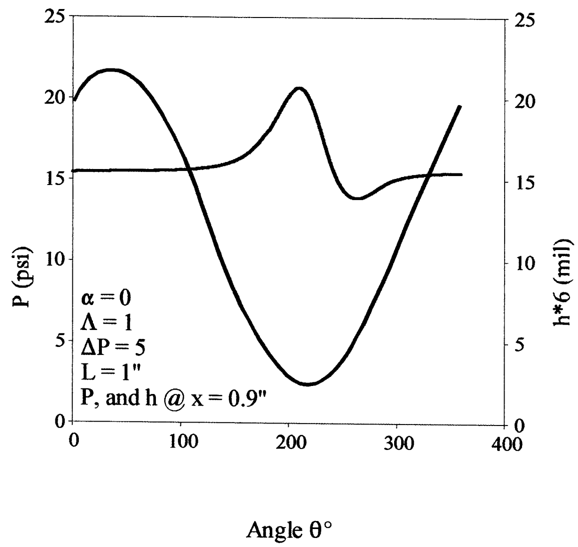
- Pressure and film equations are solved simultaneously
- The numerical method is a combination of successive over-relaxation (SOR) method and the iteration method
- Effect of top foil compliancy is taken into account by considering the neighboring pressure effect in the axial and circumferential direction on the film thickness about a node
- Applying the previous condition allows the top foil to be extensible only in circumferential direction.
- The axial pressure distribution is not imposed, but is determined from the solution of the Reynolds equation

Pressure and Film Thickness Distribution

Compliant Surface

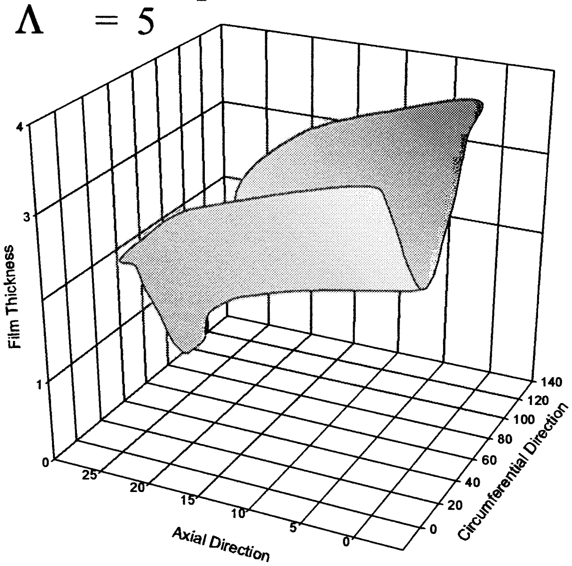


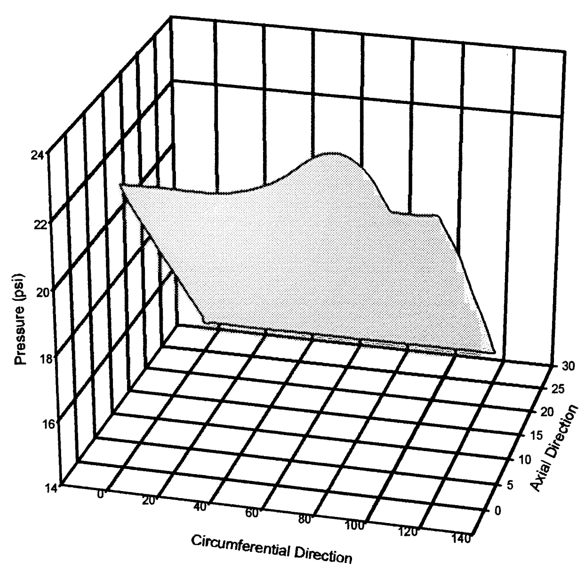
Rigid Surface



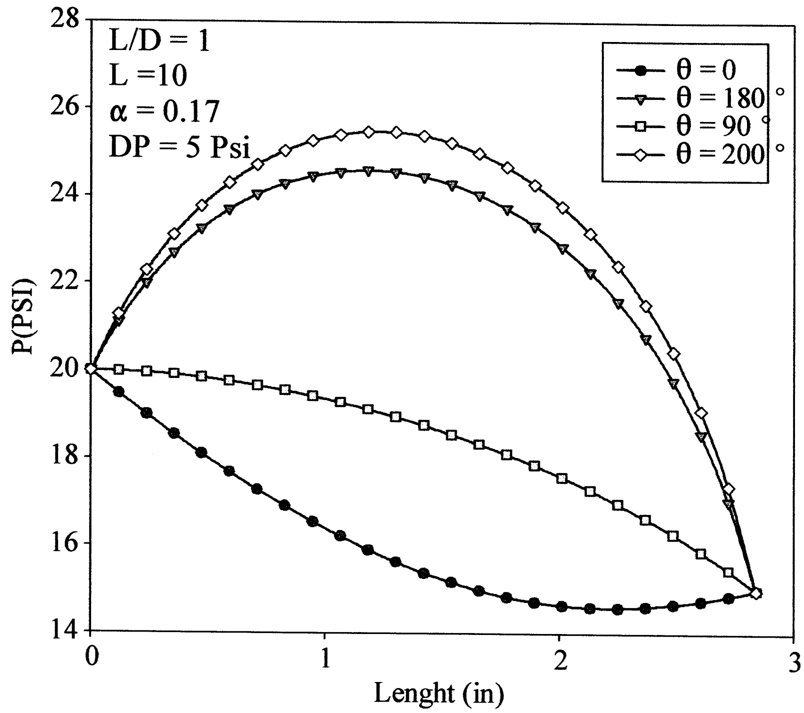
Film Thickness and Pressure Distribution

L/D = 0.5
ΔP = 7.5 psi
Λ = 5

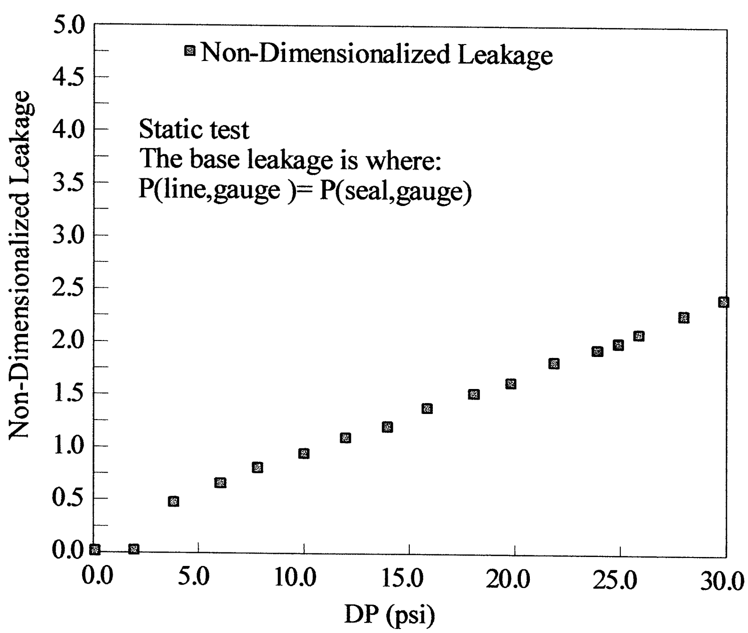




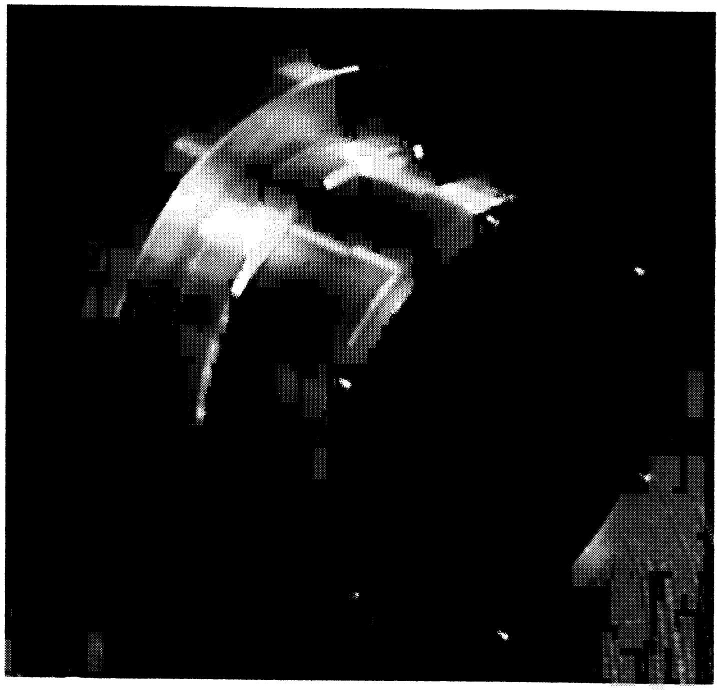
P Distribution Along the Seal at Different Circumferential Position



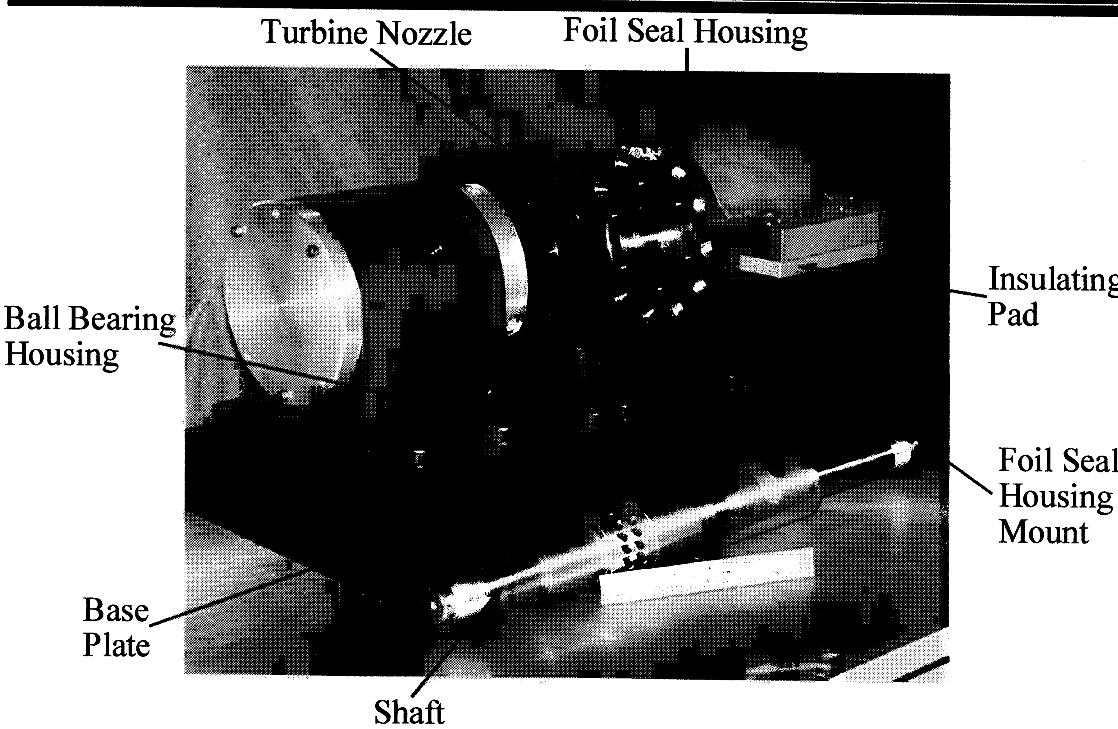
Foil Seal Leakage Test



Prototype Compliant Foil Seal Assembly



Test Apparatus



Progress

- Thermo-Hydrodynamic Coupled Analysis Developed for Foil Bearing and Seals
- Established Numerical Method
  - Reynold's Equation solved with non-symmetric B.C.s & Compliancy
  - The Viscosity-Temperature relationship employed for T_max
  - Pressures and Leakage Flow
- Theoretical/Experimental Comparison
  - Couette Approximation with empericism will provide good estimate of temperatures.
  - Comparison with available measured temperature data provides guide for conduction/convection ratios

Progress - Cont'd

- The overall design of experimental apparatus is completed
- Rig parts being fabricated
- Preliminary Foil Seal Fabricated
  - Addresss manufacturing issues
  - Lift off tests completed and successfully demonstrated
- Lubricant Coating Activities at RPI
  - Plasma Spray Vendors Identified
  - Mods to Tester to Evaluate Integrity of Coating Near Completion
  - Bearing and Seal Journals Fabricated