Overview of Turbine Seal Testing at GRC

Margaret P. Proctor & Irebert R. Delgado
NASA Glenn Research Center & U.S. Army Research Laboratory

Contributors
J. Flowers, Army; B. Steinetz, Jay Oswald, CWRU

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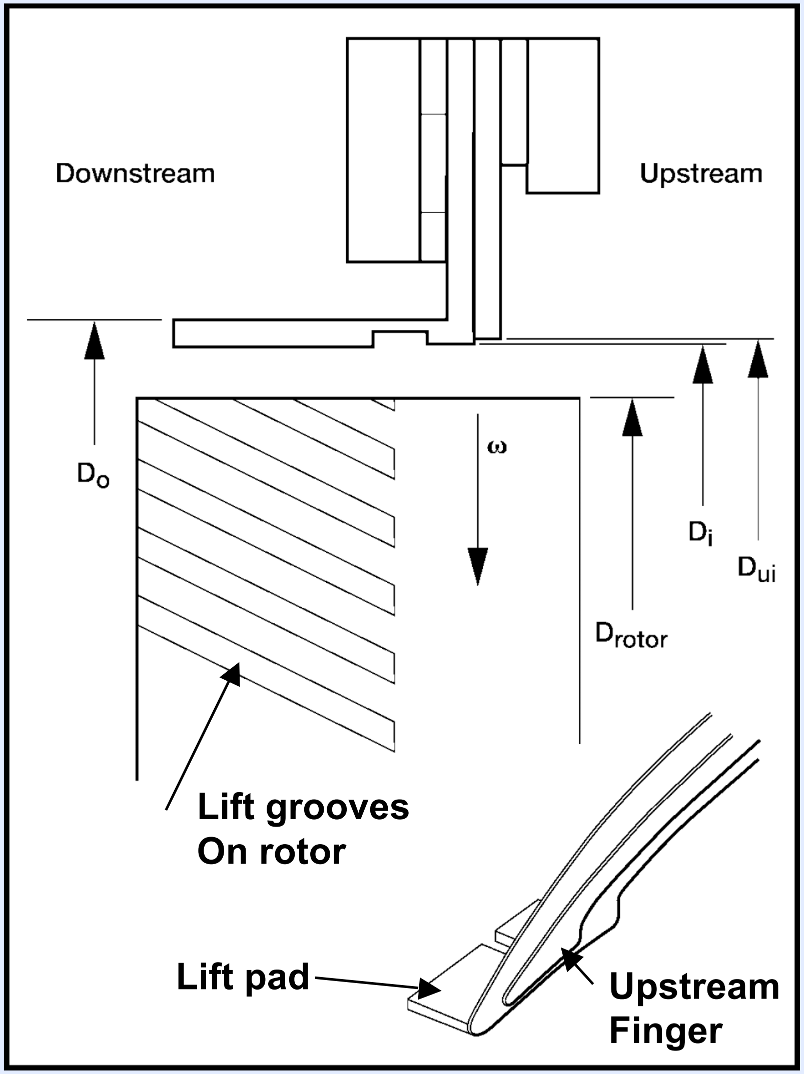
Turbomachinery Seal Development Objectives

- Evaluate feasibility of advanced seal concepts and materials of meeting next generation engine speed and temperature requirements.

- Provide a state-of-the-art turbomachinery seal test rig capable of testing seals under known and anticipated design conditions.

- Work with industry to assess and demonstrate performance of their seals prior to test in engine.

Improved Non-contacting Finger Seal



Features

- **Standard upstream fingers**

  Intentional small clearance with rotor prevents upstream finger wear.

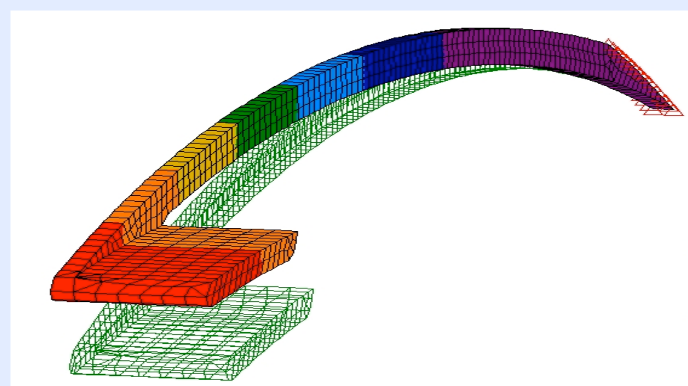
- **Lift pads only on downstream side**

  Hydrostatic pressure may be adequate to provide lift. Lift grooves, which generate hydrodynamic lift during shaft rotation may be removed based on test results.

- **Pressure forces causes seal to lift preventing contact.**

- **Small clearances promote low leakage.**

- **Structural and fluid analysis being used to determine the design geometry and performance.**



Non-Contacting Finger Seal Development - NASA GRC & U. of Akron

Objective:

Develop non-contacting finger seal to overcome finger element wear and heat generation for future turbine engine systems

Approach:

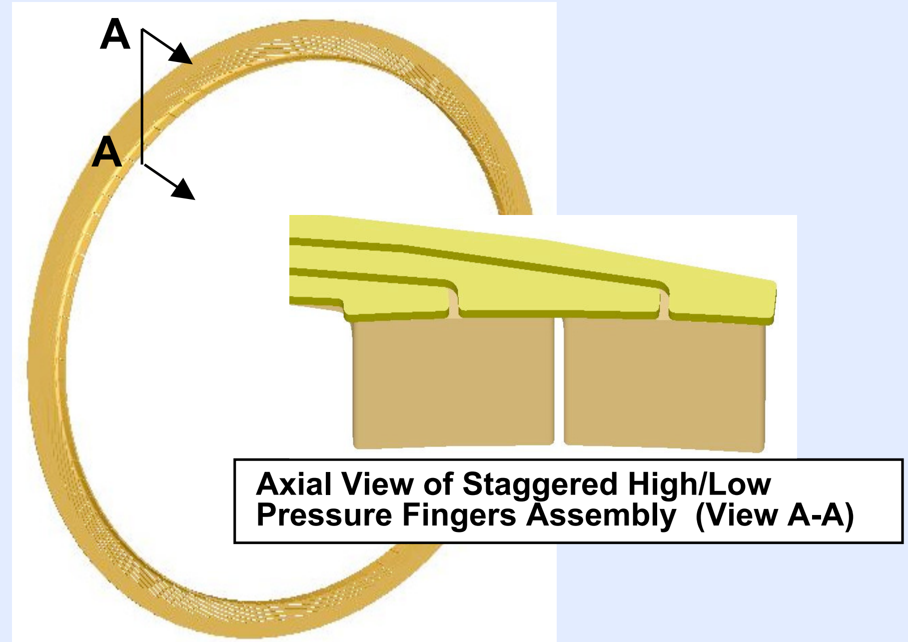
- Solid modeling for finger and pad motion/stresses
- Fluid/solid interaction for leakage evaluation
- Experimental verification

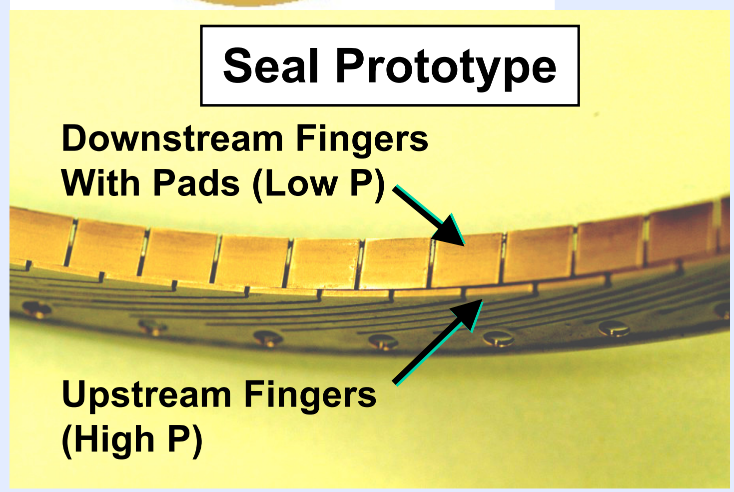
Status:

- Developed a simplified spring-mass-damper model to assess seal's dynamic response.
- CFD-ACE+ (3-D Navier-Stokes code) utilized to analyze the thermofluid behavior and to obtain stiffness and damping parameters.
- First prototype built: Testing underway

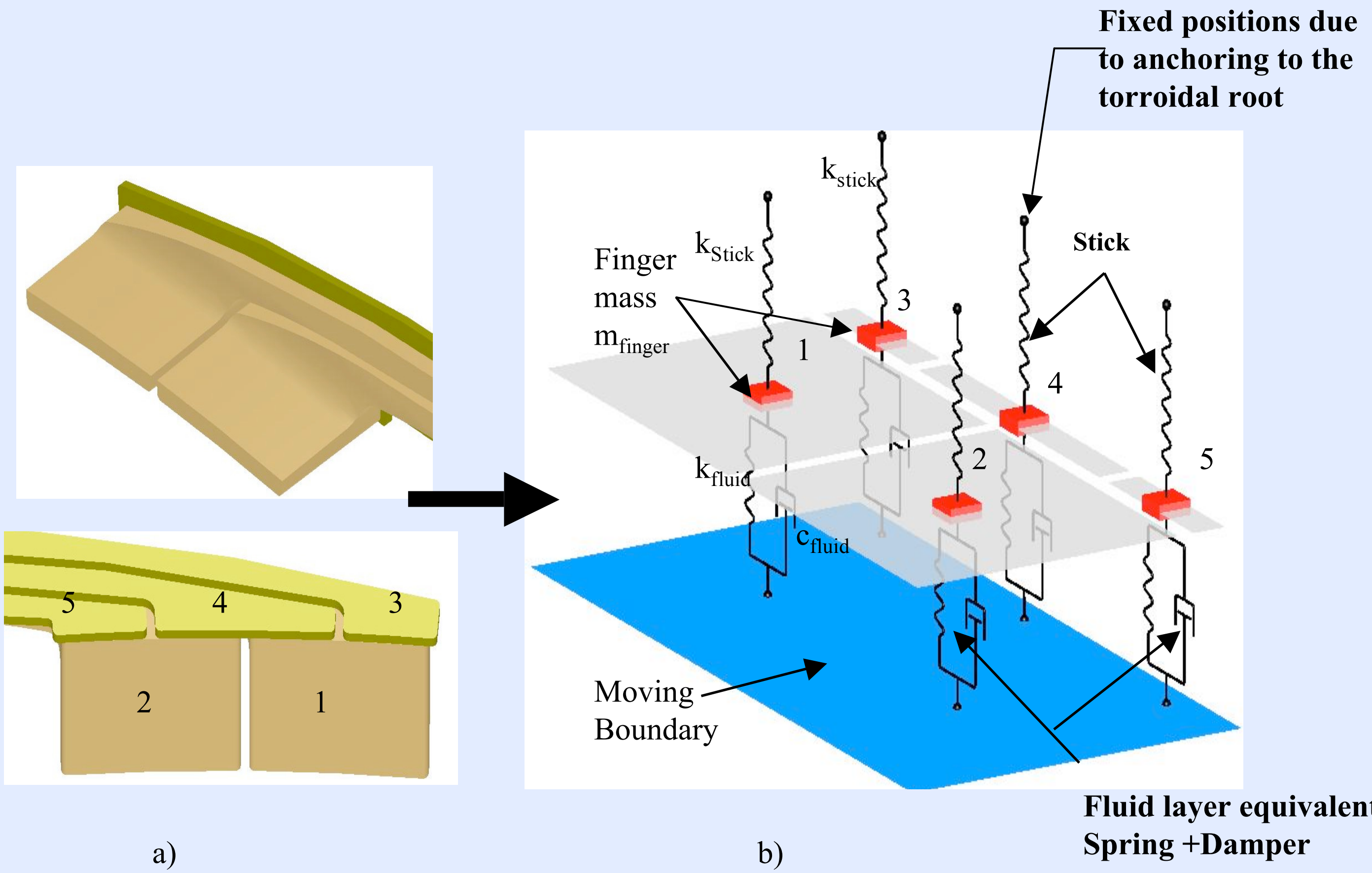
Program:

NASA/Univ. of Akron Coop. Agreement:
Dr. Braun (U. of Akron) M. Proctor, Monitor





Finger Seal Equivalent Model for Dynamic Simulation – 2-DOF



a) b)

Solid model and Equivalent Spring-Mass-Spring/Damper representation for use in the equation of motion simulation

High Temperature Turbomachinery Seal Test Rig

- Test rig is designed to test at speeds and temperatures envisioned for next generation commercial and military turbine engines.
- Test rig is one-of-a-kind. More capable than any known test rig in existence at either engine manufacturers or seal vendors.
- Temperature Room temperature thru 1500 °F
- Surface speed 1500 fps at 40,455 rpm, 1600 fps at 43,140 rpm
- Seal diameter 8.5" design; 8.308 in. design; other near sizes possible
- Seal types Air seals: brush, finger, labyrinth, film riding rim seals
- Seal pressure 250 psig maximum, reduced by current air heater

  Current air heater flange limited to 125 psig at 1500 °F

  New Air Heater capable of 250 psig to be installed this spring
- Motor drive 60 hp (60,000 rpm) Barbour Stockwell Air Turbine with advanced digital control for high accuracy/control

Test Parameters

- Seal flow vs. pressure, speed, temperature
  (Both test rig and test seal are heavily instrumented)

- Seal performance vs. simulated ramp cycles using new digital air turbine speed controller. Multiple speed step mission profile capabilities

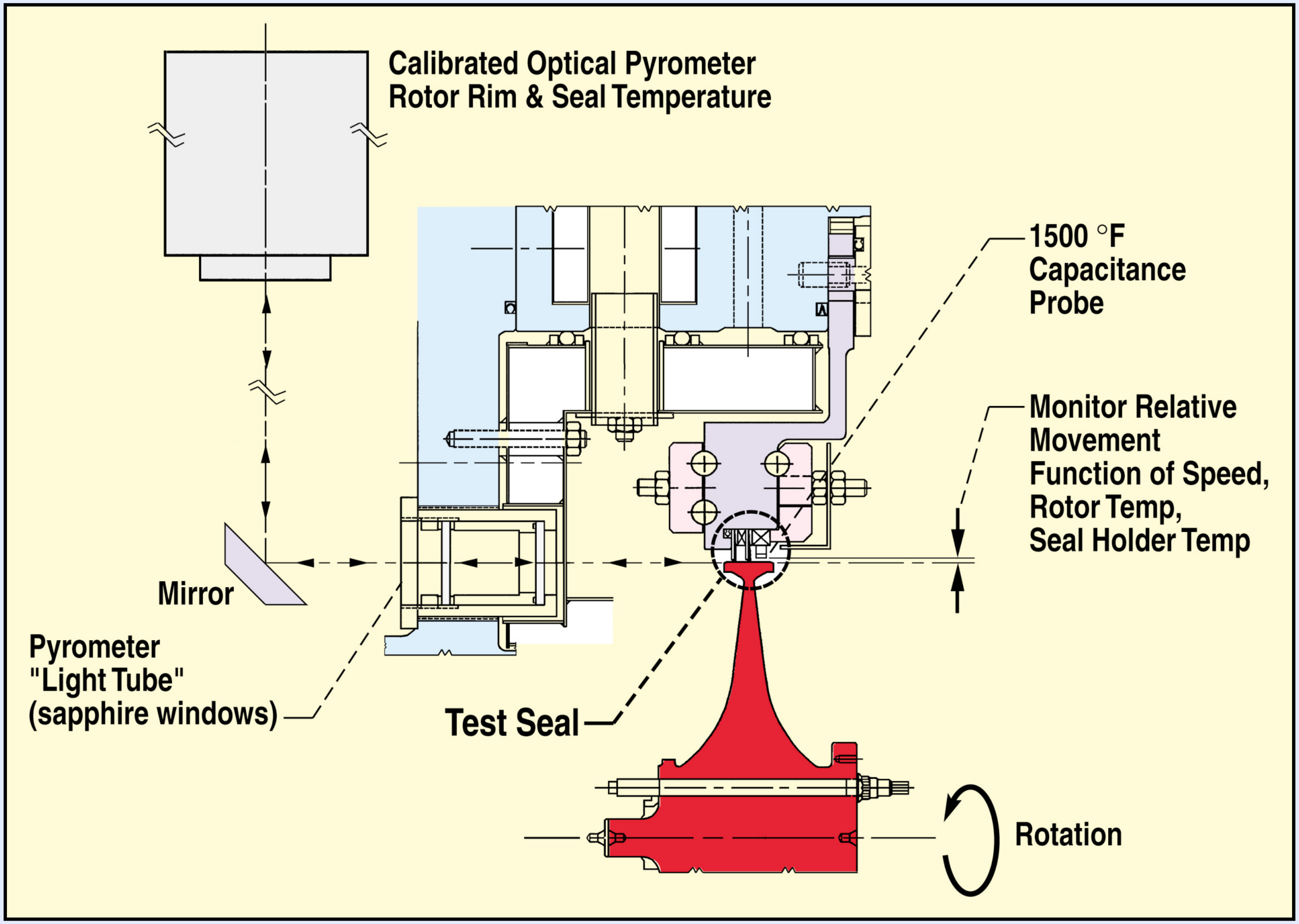
- Seal durability vs. once-per-rev rotor runout condition

- Seal durability for prescribed seal offset condition (e.g. 3 mil seal offset)

- Accelerated life tests

- Seal and coating wear

Rig Features Unique Measurement Systems



Torquemeter

- **Installed between rig and air turbine**
- **Torquetronic model ET10MS**
  - **Maximum torque rating of 22 Nm (16 ft-lb)**
  - **Maximum speed of 50,000 rpm**
  - **Absolute accuracy of 0.13 %**
    - **0.029 Nm or 0.021 ft-lb**
    - **0.032 Hp**
- **Phase shift principle**
  - **Circumferential coil in stator ring provides toroidal flux path**
  - **Toothed shaft – teeth generate sinusoidal signals in stationary coils, whose phase displacement is directly proportional to shaft twist and hence torque.**

High-Temperature, High-Speed Turbine Seal Rig

Test Rig Status - Key Accomplishments

•Achieved 1200 °F at the seal inlet.

•Determined tare torque
- at ambient conditions up to 34,400 rpm.
- at 650, 800, 1000, 1200 °F up to 32,500 rpm.

•Checkout tests w/ brush seal conducted at ambient, 600, 800, 1000 °F.

•Tested of Honeywell's finger seal up to 1200 fps, 1200 °F, and 75 psid. (AIAA-2002-3793, NASA/TM--2002-211589, ARL-TR-2781)

•Conducted static testing with highly instrumented rotor.

•Tested 4-knife labyrinth seal for baseline comparisons.

•Tested 3 new seal concepts for 2 small businesses.

Test Rig Status

Open issues:

- Rotordynamic instabilities limit max speed to 32,500 rpm.

  Planned action: Install redesigned squeeze film dampers and check rotordynamic performance.

- Rig operating temperature and pressure is limited by current air heater.

  Planned action: Install new air heater and upgrade hot piping and insulation.

Current Schedule

Test Arora's non-contacting seals	Oct 04-Mar 05
Cylindrical Seal Baseline Tests	March 2005
Install redesigned dampers	March-April 2005
Install new air heater	April-July 2005
Test Non-contacting Seals:	
NASA's Improved NC Finger Seal	Aug-Sep 2005
U. of Akron	Aug-Sep 2005

Summary Points

- Current research focuses on non-contacting seal designs.
- NASA/Army research team collaborates with industry.
- State-of-the-art turbine seal test stand is operational.
  - Unique combinations of high speed, high pressure, and high temperature
- Upgraded test facility has
  - Improved heater temperature and pressure capability
  - Improved speed control with Barbour Stockwell air turbine motor/controller
  - Test control through Modicon PLC
  - Torquemeter
- Test stand and facility is an asset to the U.S. Engine/Seal Community.
  - 1st customer was Honeywell for JTAGG III Engine Seal Program
  - Non-contacting seal designs for SEC program
  - Mohawk's Foil Seal
  - Arora's hot seal designs for TBCC's Revolutionary Turbine Accelerator