The basic approach for analyzing hydrostatic bearing flows at MSFC is three pronged. First, the Hydrostatic Bearing Team has responsibility for assessing and evaluating flow codes, evaluating friction, ignition, and galling effects, evaluating wear, and performing tests. Secondly, the Office of Aerospace and Exploration Technology Turbomachinery Seals Tasks consist of tests and analyses. Thirdly, MSFC in-house analyses utilize one-dimensional bulk-flow codes; computational fluid dynamics (CFD) analysis is used to enhance understanding of bearing flow physics or to perform parametric analyses that are outside the bulk-flow data base. As long as the bulk-flow codes are accurate enough for most needs, they will be utilized accordingly and will be supported by CFD analysis on an as-needed basis.

Overview

- Hydrostatic Bearing Team formed 02/16/90
  - Assess and validate flow codes
  - Evaluate friction and ignition effects
  - Evaluate wear and galling effects
  - Verify design by HPOTP pump-end test (Rocketdyne IRAD)
    - TTB in October / November timeframe

- OAET Turbomachinery Seals Tasks
  - Three tasks in place -- E3b, E4e, and LSVT13
  - One task pending -- LSVT8 (NRA)

- In-house CFD analyses
  - Baseline damping seal
  - Code validation
  - Rotordynamic coefficients
  - Baseline hydrostatic seal
  - Flow cavity parameters
  - Flow visualization
MSFC Turbomachinery Working Group Summary

<table>
<thead>
<tr>
<th>Work Element Title</th>
<th>Prior</th>
<th>89</th>
<th>90</th>
<th>91</th>
<th>92</th>
<th>93</th>
<th>94</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3e. Damping Seal Rotor Support</td>
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<td>Design criteria for rolling element/damping seal assemblies for high side loads; Results led to current TTB validation for HPOTP</td>
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<tr>
<td>E4e. Damping Seals for Turbomachinery</td>
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<td>Test verification of dynamic properties of damping seals; Wyle tester; measures rotodynamic coefficient density; Test In progress</td>
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<tr>
<td>LSVT8. Verification of Damping Seal Modeling Techniques</td>
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<td>Hydrostatic bearing data base for code validation; NRA contractor TBD</td>
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<tr>
<td>LSVT13. Experimental Verification of Rotordynamic Analysis</td>
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<td>Hydrostatic damping bearing data for rotordynamic coefficients; internally and externally fed HPOTP turbine end configuration</td>
</tr>
</tbody>
</table>

Flight Configuration HPOTP
Phase II
Preburner Pump Bearing Package
Experimental Verification of Rotordynamic Analysis
MSFC Program Status

- Complementary Damping bearing development initiated in October
  - Verifies rotordynamic coefficient calculations for hydrostatic bearings

- Test four hydrostatic bearings in modified long life tester
  - HCFC test fluid
    - Two bearings internally fed through the shaft
      - Conventional and damping designs TBD
    - Two bearings internally fed through the stator
      - Conventional and damping designs TBD

- Extracts all rotordynamic coefficients
  - Measures leakage and frictional torque

- Conceptually designs new HPOTP turbine end package
  - Includes lowest whirl ratio bearing tested
  - Provides manufacturing estimate
Potential HPOTP Turbine End Hybrid Bearing Retrofit

Internally Fed Hydrostatic Bearing/Damping Seal

6 Rotor Feed Holes @ 0.219 in Dia. Each

Shaft Spacer Holes Angled 50° Counter To Rotation - Deswirls Seal Inlet Flow

Internally Fed Damping Bearing

Leakage

Smooth Land

Axial Gates

Rough Area

Inlet Flow

Leakage

QLVP 880518

- George Von Pragenau, NASA-MSFC, Design Concept
In-house CFD Analysis

- 3-D analysis; 60° slice of bearing
- Single-phase incompressible Navier-Stokes analysis; constant $-\gamma H_2$
- Rotational Reynolds number based on annulus width $\sim 4.8 \times 10^4$
- Multi-block solution in progress with FDNS3D code
  - 3-dimensional pressure-based finite-difference Navier-Stokes solver
  - PISO algorithm with modified Stone's solver
  - Convection term differencing
    - Central
    - $3^{rd}$-order upwind
    - $2^{nd}$-order upwind
- K-ε turbulence model
  - Two high-Reynolds-number models
  - Four low-Reynolds-number models
In-House CFD Analysis

Configuration

Baseline Hydrostatic Seal

Baseline Damping Seal

In-House CFD Analysis

Typical Grid
Summary

- Hydrostatic Bearing Team meeting regularly with Rocketdyne design organization
  - TTB validation for HPOTP set for October/November 1991 timeframe

- OAET tasks defined
  - Data bases for determining rotordynamic coefficients and flow physics are evolving

- Bulk-flow computer design codes are in place and being extended
  - CFD being applied to support bulk-flow code development for assessing secondary flows in damping seal pockets

- In-house analysis initiated to assess generic flows related to hydrostatic bearings