An example of parameter identification
Identification of force coefficients in a test damper

Luis San Andrés

Sanjeev Seshagiri, Paola Mahecha

Research Assistants

Sponsor: Pratt & Whitney Engines

SFD EXPERIMENTAL TESTING & ANALYTICAL METHODS DEVELOPMENT
P&W SFD test rig

Shaker assembly (Y direction)
Shaker assembly (X direction)
Static loader
SFD test bearing
P & W SFD Test Rig – Cut Section

Test rig main features

- **Journal diameter:** 5.0 inch
- **Film clearance:** 5.1 mil
- **Film length:** 2 x 0.5 inch
- **Support stiffness:** 22 klbf/in

Diagram:
- Test Journal
- Bearing Cartridge
- Piston ring seal (location)
- Supply orifices (3)
- Circumferential groove
- Flexural Rod (4, 8, 12)
- Main support rod (4)
- Pedestal
- Journal Base

Inch scale: 0 1 2 3 4 5
Objective & task

Evaluate dynamic load performance of SFD.

Dynamic load measurements: circular orbits (centered and off centered) and identification of test system and SFD force coefficients.
Circular orbit tests

- Frequency range: 5-85 Hz
- Centered and off-centered, $e_s/c = 0.20, 0.40, 0.60$
- Orbit amplitude $r/c = 0.05 – 0.50$

ISO VG 2 Oil

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity at 73.4 °F [cPoise]</td>
<td>2.95</td>
</tr>
<tr>
<td>Density [kg/m³]</td>
<td>784</td>
</tr>
<tr>
<td>Inlet pressure [psig]</td>
<td>7.5</td>
</tr>
<tr>
<td>Outlet pressure [psig]</td>
<td>0</td>
</tr>
<tr>
<td>Radial Clearance [mil]</td>
<td>$c$</td>
</tr>
<tr>
<td>Journal Diameter [inch]</td>
<td>5.0</td>
</tr>
<tr>
<td>Central groove length [inch]</td>
<td>$L$</td>
</tr>
<tr>
<td>Land length, L [inch]</td>
<td>$L$</td>
</tr>
<tr>
<td>Total Length [inch]</td>
<td>$3L$</td>
</tr>
</tbody>
</table>
Typical circular orbit tests

- Frequency range: 5-85 Hz
- Centered $e_S = 0$
- Orbit amplitude $r/c = 0.66$

![Graph showing X Displacement vs. Y Displacement and Forces vs. Frequency](image-url)
Typical circular orbit tests

- Frequency: 85 Hz
- Off-centered at $e_s/c = 0.31$
- Orbit amplitude $r = 0.05 - 0.5$

**Graphs:**
- Y Displacement [mil] vs. X Displacement [mil]
- Y Load [lbf] vs. X Load [lbf]

**Legend:**
- **Red Arrow:** motion ($y$ vs. $x$)
- **Blue Arrow:** Forces ($f_y$ vs. $f_x$)
Typ system direct complex stiffnesses

\[ H_{xx} \]

\[ H_{yy} \]

Real part

Imaginary part

From test data

From IVF

From test data

From IVF

From test data

From IVF

From test data

From IVF

r/c = 0.66, centered \( e_s = 0 \)
Typ. system direct complex stiffness $H_{xx}$

$H_{xx}$

Re($H_{xx}$) [lbf/in]

Im($H_{xx}$) [lbf/in]

Frequency [Hz]

Excellent correlation between test data and physical model

REAL PART = dynamic stiffness

IMAGINARY PART proportional to viscous damping

$r/c = 0.66$, centered $e_s = 0$

$K - \omega^2 M$

$\omega C$
Test cross-coupled complex stiffnesses

One order of magnitude lesser than direct impedances = Negligible cross-coupling effects

\( r/c = 0.66 \), centered \( e_s = 0 \)
SFD force coefficients

Difference between lubricated system and dry system (baseline) coefficients

\[ C_{SFD} = C_{\text{lubricated}} - C_s \]

\[ M_{SFD} = M_{\text{lubricated}} - M_s \]

\[ K_{SFD} = K_{\text{lubricated}} - K_{\text{sh}} \]

DRY system parameters

\[ K_s = 21 \text{ klbf/in} \]
\[ M_s = 40 \text{ lb} \]
\[ C_s = 7 \text{ lbf-s/in} \]

Nat freq = 73-75 Hz
Damping ratio = 0.04
SFD damping coefficients

Damping increases mildly as static eccentricity increases

$C_{\text{YY}} \sim C_{\text{XX}}$ for circular orbits, independent of static eccentricity
$M_{xx}$ decreases with orbit radius ($r$) for centered motions. Typical nonlinearity

$M_{xx} \sim M_{yy}$
Conclusions

- **SFD test rig:** completed measurements of dynamic loads inducing small and large amplitude orbits, centered and off-centered.

- Identified SFD damping and inertia coefficients behave well. IVFM delivers reliable and accurate parameters.

- Comparison to predictions are a must to certify the confidence of numerical models.
References


