EXPERIMENTAL FORCE COEFFICIENTS IN A SEALED ENDS SFD SUPPLIED WITH LUBRICANT THROUGH A CHECK VALVE

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SFD Test Rig

Test rig built with funds from Pratt & Whitney Engines: A unique research program, 10 years & ~ 1.2M USD funding.

Journal diameter, $D$ 127 mm (5 in)
Film Length, $L$ 25.4 mm (1 in)
Film clearance, $c$ 0.279 mm (11 mil)

ISO VG2
Viscosity, $\mu$ 2.6 mPa-s (at 23 °C)
Density, $\rho$ 800 kg/m³
Multiple-year test program (2008-2018)

To explore novel SFD designs & benchmark SFD empirical data.

Develop & validate SFD force performance model.

Optimize SFD influence on rotor dynamics.
Past TRC Projects on SFD 2015-2017

- Linear-Nonlinear Force Coefficients for SFDs: Experimental Response of a Sealed Ends SFD to Intermittent Impact Loads
- Experimental Response of an Open Ends SFD vs. a Sealed Ends SFD
- Effect of Lubricant Supply Pressure on SFD Performance: Ends Sealed with o-rings and Piston Rings

Best paper Award: S&D Committee, 2019 Turbo-Expo Conference

A sealed ends SFD gives > 10X force coefficients (C,M) than with an open ends SFD.

SFDs should produce more damping as whirl orbit amplitude increases. The risk of too much damping → overdamped system
In a SFD, the film pressure \( P \) and tangential force \( F_T \) are proportional to the squeeze film velocity:

\[
v_s = r \omega = \text{orbit amplitude (r) x whirl frequency (}\omega)\]

\[
P \sim \frac{v_s}{c^2} \quad F_T \sim C v_s
\]

where \( C \) is a damping coefficient.

UG student (largely unsupervised) conducted a batch of dynamic load tests with an o-rings sealed SFD operating with a circular centered orbit while the velocity \( v_s = 0.7 \text{ in/s} \) is constant.

\[
c = 279 \mu m \\
e/c = 0.0 \\
P_{in} = 10 \text{ psig} \\
1 \text{ check valve}
\]
Pressure vs. time – o-ring sealed SFD

As orbit size \( r \) increases, same squeeze velocity \( v \) produces different pressure profiles. Large orbit decompresses o-rings and damper leaks.

\[ v = r \omega = \text{orbit amplitude} \times \text{whirl frequency} \]

Note pressure drops as \( r \) increases.
O-ring sealed SFD

Small orbit amplitude: O-rings do not loose compression → end seals are tight and no air ingestion occurs.

Large orbit amplitude: O-rings loose compression → end seals ”open” to draw air into the film.
For squeeze velocity $v_s=0.7 \text{ in/s}$:

**Damping** decreases as orbit size increases (or whirl frequency decreases), likely due to air ingestion.

**Inertia coefficient** → 0 for largest orbit size ($r=0.3c$).

Quite odd results! More tests and rationale needed!
Proposal: Objective and tasks

Quantify the dynamic forced performance of O-rings sealed SFD

- Oil inlet through a mechanical check valve (to avoid back flow).
- Low lubricant supply pressure (20 psig or less). Insufficient flow may produce air ingestion.
- Keep squeeze velocity ($v_s$) constant = (3) $r x (3) \omega = \text{orbit size} \times \text{whirl frequency}$.

**Deliverable:** report with details on o-rings selection, installation and troubleshooting, measurement procedure and experimental damping and inertia force coefficients.
<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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<tr>
<td>Support for student (20 h/week) x $ 2,200 x 12 months</td>
<td>$ 26,400</td>
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<tr>
<td>Fringe benefits (2.3%) and medical insurance ($210 /month)</td>
<td>$ 3,173</td>
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<td>Tuition &amp; allowable fees for three semesters</td>
<td>$ 17,187</td>
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<td>Supplies for test rig (new journal with grooves resized)</td>
<td>$ 3,240</td>
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<td><strong>Total requested</strong></td>
<td><strong>$ 50,000</strong></td>
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Work is of interest for aircraft (military) engines and semi-floating ring bearings for turbochargers. The TL research program on SFD reaches its 30 year mark with many practical and computational advances delivered to sponsors.
Thanks TRC for many years of support

We have grown old together!

Questions (?)