Imbalance Response of Hybrid Flexure Pivot Tilting Pad Gas Bearing

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Introduction

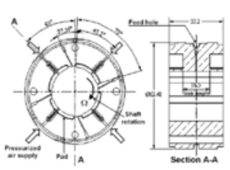
Tilting pad bearings offer inherent rotordynamic stability thus allowing microturbomachinery to operate at high rotational speeds. Experimental research verifies the rotordynamic performance of rotor-gas bearing system.

Facts about flexure pivot tilting pad gas bearings

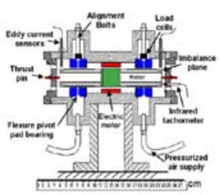
- •Reduced or null cross coupled stiffnesses
- •Simpler and cheaper cost of operation tha foil bearings
- •No pivot wear
- •Wire EDM manufacturing for tolerance control
- •Less load capacity than (life limited) ball bearings

Apparatus Setup and Method

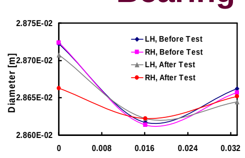
After assembling rotor-bearing test rig, turn on drive motor and accelerate shaft to a speed of 50 krpm. Then turn off drive motor and collect rotor vibration during coast down. LabVIEW® and ADRE® data acquisition systems used. Mathcad® and Excel® used for data analysis.

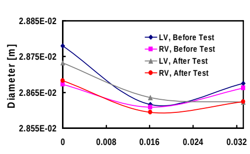


Parameter	Value	Unit
Rotor mass, M	0.825	kg
Rotor diameter, D_j	28.55 ± 0.001	mm
Bearing axial length, L	33.2	mm
Pads number and arc length	4 (72 °)	
Pad pivot offset	60%	
Nominal preload	0.3	
Pad mass, m_p	10.85	g
Pad mass moment of inertia, I_p	0.253	g-mm^2
Web rotational stiffness, $K_{\delta\delta}$	20	Nm/rad
Number of feed orifices	4	
Feed orifice diameter	0.62	mm

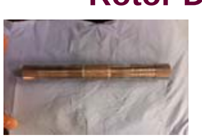


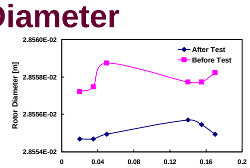
Bearing Diameter





Rotor Diameter

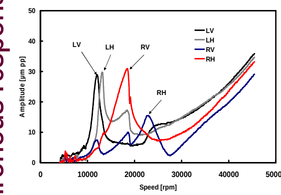




Test Results

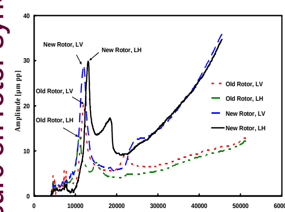
- • Peak amplitudes of rotor motion occur at different critical speeds because of bearing asymmetry.
- • After crossing critical speed, rotor motion amplitudes decrease
- • Secondary and tertiary peak amplitudes reflect passage through various critical speeds.
- • Gas feed pressure affects greatly the bearings' stiffness and damping
- •The rotor keeps a static centered position at high shaft speeds. Rotor displaces towards bearings' bottom pads as speed decreases
- •Drag forces from bearing are of viscous and dry-friction type at high and low shaft speeds, respectively
- •Gas bearings offer stable response – no signs of subsynchronous motions

Effect of supply pressure on rotor synchronous response



5.08 bar

The amplitude peaks at different speed indicates different critical speeds. Secondary ant tertiary peak corresponds to primary peaks at the other locations.



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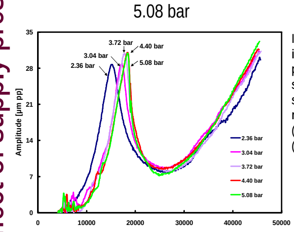
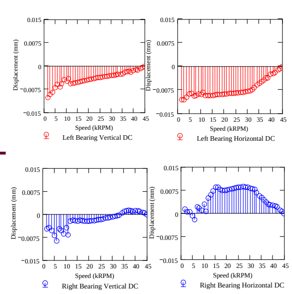
Severe rubbing caused amplitude to increase after passing critical speed. Poor rotor balance and bearings with unequal clearances may have lead to rotor large motions at highest shaft speeds



Increasing feed pressure increases both amplitude of peak vibration and critical speed of rotor-bearing system. As feed pressure raises, the bearing stiffness (damping) increases (decreases)

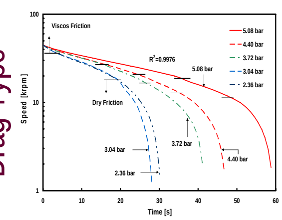
Rotor Displacement



At highest speeds, rotor stays at the center of the bearing. The rotor begins to displace off the center as the speed decreases.

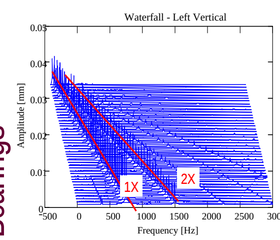
At higher feed pressures, the rotor maintains the position at the center even at the low end of shaft speed.

Drag Type



Rotor coast down speed measurements show the type of drag in the bearings. The drag force in the linear region is viscous type, and in the nonlinear region is of coulomb friction type. The region between these two is a transition zone.

Stability of Bearings



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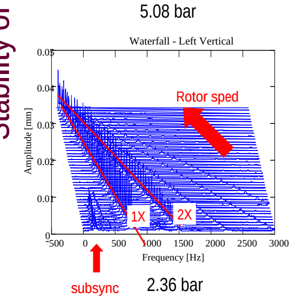

2.36 bar

Waterfall plots show frequency components of rotor motion. Subsynchronous motions are apparent for operation with low supply pressure and at highest shaft speeds (> 50 krpm). Small magnitude of subsynchronous frequency indicates bening stable characteristic of flexure pivot tilting pad gas bearing.

Summary

- •Inherent stability of test gas bearings offers great potential for rotor-bearings in microturbomachinery.
- •Gas supply pressure affects bearings' stiffness and damping, thus leading to increased critical speeds and loss of system effective damping.
- •Little drag at high speeds is of viscous type, with dry friction (large drag) occurring at low speeds due to surfaces' contact.
- •Severe rubbing at high speeds caused unexpected large motions with quick shut down of rotor-bearing system

Acknowledgement

This study is supported by National Science Foundation under REU#0552885 program.