Externally Pressurized Gas Bearings for Use in Rotating Equipment
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Discussion Topics

1. Porous Media Technology – background

2. Externally-Pressurized Gas Bearings
   a) Radial Bearings
   b) Thrust Bearings
   c) Gas Bearings as a Seal
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Porous Media Technology Background
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Common Externally Pressurized Gas Bearings

**Air Bushings**

The New Way air bushing is designed to make air bearing technology readily available to engineers with pre-existing designs based on round shaft guides. These components run on standard precision steel shafting and are available in Metric or English sizes.

**Air Bars**

New Way offers a line of modular air bearing components specifically designed to meet the non-contact glass-handling requirements of the Flat Panel Display and Solar Module manufacturing processes, including the new low-cost, high performance Transition Zone Air Bar.

**Air Bearings**

The ideal components for building frictionless linear motion, New Way Flat Air Bearings were the original standard, off-the-shelf, porous media air bearing product line, developed by New Way in the 1980's. They are now available in round or rectangular configurations.

**Radial Air Bearings**

The ideal components for building frictionless rotary motion, New Way Radial Air Bearings provide a fast, made-to-order solution. In either concave or convex configurations, this new product line gives you all the differential advantages of New Way standard air bearings.

**VPL Air Bearings**

For applications where pre-loading is difficult or impossible, Vacuum Preloaded Air Bearings add vacuum to New Way Porous Media™ Technology. Simply then, these bearings hold themselves down while simultaneously lifting themselves from the guide surface.
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Gas Bearings - Application Example

[Image of a machine with gas bearings]

- Zero Friction
- Easy to use
- Robust
- High Performance
- Silent and Smooth

NEWWAY®
Air Bearings
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings - Application Examples
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings – Application Example
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings – Application Example
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Comparison of Bearing Types + Attributes of Gas Bearings

- No friction (no heat)
- No wear
- Straighter motion
- Silent/smooth
- Eliminates lubrication
- High speeds
- High dynamic stiffness
- Damping
Externally Pressurized Gas Bearings for Use in Rotating Equipment
Detailed Look at an Aerostatic Gas Bearing
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings – Lift-Load Curves

[Diagram showing lift-load curves for gas bearings with 60 psi and 80 psi pressure levels]

Guide Surface: Steel
Externally Pressurized Gas Bearings for Use in Rotating Equipment
Orifice vs. Porous Gas Bearings
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Why is Restriction Needed?

Externally Pressurized Gas Bearings for Use in Rotating Equipment

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Externally Pressurized Gas Bearings for Use in Rotating Equipment

Why is Restriction Needed?
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Why is Restriction Needed?
There are restrictive orifices inserted in the ID holes. As the shaft moves toward an orifice, the restriction in the bearing gap increases relative to the orifice restriction, and so the orifice lets in more of the supply pressure, pushing the shaft back to center. There is an equal and opposite complimentary change in pressures on the opposite side. This is compensation.
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Why is Restriction Needed?

Flow is proportional to the cube of the gap
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Why is Restriction Needed?
By positioning the annular groove under the porous media, it feeds millions of submicron-sized orifices that are formed naturally and very evenly distributed across the face.
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Orifice vs Porous Gas Bearing – Pressure Profiles / Compensation

- Multiple orifices with no grooves
- Multiple orifices with distribution grooves
- Single orifice no grooves
- Single non-restrictive input port with depth and width of grooves providing restriction
- Full porous face. With 10's of millions sub-micron pores evenly spaced across the face
### Externally Pressurized Gas Bearings for Use in Rotating Equipment

**Air Quality**

<table>
<thead>
<tr>
<th>QUALITY CLASS</th>
<th>DIRT (Particle size in micron)</th>
<th>WATER Pressure Dew Point °F @ 100 PSIG</th>
<th>OIL (including vapor mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1</td>
<td>-94</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>-40</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>-4</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>+37</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>+45</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>+50</td>
<td>-</td>
</tr>
</tbody>
</table>

**Recommended**

**Minimum Specs**

- **Zero Friction**
- **Easy to Use**
- **Robust**
- **Inexpensive**
- **High Performance**
- **Silent and Smooth**

![Diagram of Externally Pressurized Gas Bearings](image-url)
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Radial Gas Bearings
Externally Pressurized Gas Bearings for Use in Rotating Equipment
Radial Gas Bearing Application
Externally Pressurized Gas Bearings for Use in Rotating Equipment
Radial Gas Bearing Application

ZERO FRICITION
ZERO WEAR
EASY TO USE
INEXPENSIVE
HIGH PERFORMANCE
SILENT AND SMOOTH

NEWWAY®
aired bearings
Externally-Pressurized Gas Tilting Pad (or sleeve) Bearings enable non-contact, oil-free operation. These externally pressurized air bearings employ the same mounts as current hydrodynamic oil-based bearings (not compliant foils or flexures), so that high stiffness and damping can be maintained with an easy path to retrofit. A variety of input gases in addition to air can be used – including process gas.
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Radial Gas Bearings – High-Speed Bunker Testing
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Radial Gas Bearings – Technology Attributes

- No wear (frictionless)
- No dry running at start-up; eliminates no-start potential
- Requires similar real estate as hydrodynamic oil bearings – retrofit applications possible
- Long life
- Higher speeds without heat
- Adjustable damping (controlling gaps)
- Low air flow
- Anticipate extreme high temperature capability
- Familiar mounting geometries
- Lower maintenance than oil bearings
- Can serve as bearing AND seal in certain situations
- Run on process gas in the bearing gap
- Less peripheral equipment (less complexity, smaller footprint, less weight)
- Less complexity than magnetic bearings
- Does not require back-up bearings (as magnetic bearings do)
- Air bearings continue to run hydrodynamically without failure if air supply stopped

EXTERIALLY PRESSURIZED GAS BEARINGS FOR USE IN ROTATING EQUIPMENT

ZERO FRICITION
ROBUST
EASY TO USE
HIGH PERFORMANCE
SILENT AND SMOOTH

NEWWAY
air bearings
Externally Pressurized Gas Bearings can be used in various applications
- Compressors
- Pumps
- Motors
- Turbo Expanders
- Test Rigs and balance equipment
## Externally Pressurized Gas Bearings for Use in Rotating Equipment

Comparison with Other Technologies

<table>
<thead>
<tr>
<th>Feature</th>
<th>Ext Pressurized Gas Bearing Technology</th>
<th>Mag Bearing Technology</th>
<th>Oil Bearings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil-free operation</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Operable in process gas stream in bearing gap</td>
<td>Yes</td>
<td>Yes/No</td>
<td>No</td>
</tr>
<tr>
<td>Anticipate operability on steam in the bearing gap</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Wear</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
</tr>
<tr>
<td>Bearing contact at zero rpm</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Control system needed</td>
<td>None or minimal</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Back-up bearings needed</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Overall turbo equipment system footprint, compared to when using hydrodynamic bearings</td>
<td>Less</td>
<td>Less</td>
<td>NA</td>
</tr>
<tr>
<td>Cost compared to hydrodynamic bearings</td>
<td>Similar</td>
<td>Higher</td>
<td>NA</td>
</tr>
<tr>
<td>Damping and stiffness, compared to hydrodynamic bearings</td>
<td>Similar-done by controlling gaps</td>
<td>Controlled electronically</td>
<td>NA</td>
</tr>
<tr>
<td>Complexity compared to oil bearings</td>
<td>Simpler</td>
<td>More complex</td>
<td>NA</td>
</tr>
<tr>
<td>Physical size of bearings, compared to oil brgs</td>
<td>Similar</td>
<td>Larger</td>
<td>NA</td>
</tr>
<tr>
<td>Compatibility for retrofitting into existing turbo equip</td>
<td>Compatible</td>
<td>Not always compat</td>
<td>NA</td>
</tr>
<tr>
<td>Load carrying capacity compared to oil bearings</td>
<td>400 psi*</td>
<td>70-80 psi</td>
<td>&gt;200 psi</td>
</tr>
<tr>
<td>Can function as bearing and seal simultaneously</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

* Under certain circumstances
# Externally Pressurized Gas Bearings for Use in Rotating Equipment

## Radial Gas Bearings – Comparison with Other Technologies

### Rating of Bearing Types vs. Performance Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Oil Bearing</th>
<th>Magnetic Bearing</th>
<th>Foil Bearing</th>
<th>Flexure/Pivot Hybrid-Type Bearing</th>
<th>Externally-Pressurized Gas Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Friction at Start</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Service Cost</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Heat Generation</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Process Compatibility</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Shear/Speed Load</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Damping</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Total Score</td>
<td>12</td>
<td>15</td>
<td>15</td>
<td>17</td>
<td>21</td>
</tr>
</tbody>
</table>

Ranking Key: 3=Superior Rating   2=Average Rating   1=Low Rating

*Above table taken from Turbomachinery International Nov/Dec 2014 Article “Get Your Bearings Straight”*
**Externally Pressurized Gas Bearings for Use in Rotating Equipment**

**Radial Gas Bearings – Family of Sizes**

representative dimensional data shown below – Subject to change based on various design factors - custom sizes available

<table>
<thead>
<tr>
<th>Bearing Dia “A” (mm)</th>
<th>Pad Width “B” (mm)</th>
<th>Cartridge OD “D” (mm)</th>
<th>Load Capab @4 bar input</th>
<th>Load Capab @8 bar input</th>
<th>Load Capab @80 bar input</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>25</td>
<td>65</td>
<td>188N (42 lbf)</td>
<td>377N (85 lbf)</td>
<td>3,77kN (848 lbf)</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
<td>105</td>
<td>483N (108 lbf)</td>
<td>965N (217 lbf)</td>
<td>9,7kN (2.17 klbf)</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>135</td>
<td>754N (170 lbf)</td>
<td>1.51kN (339 lbf)</td>
<td>15.1kN (3.39 klbf)</td>
</tr>
<tr>
<td>75</td>
<td>75</td>
<td>200</td>
<td>1.7kN (381 lbf)</td>
<td>3.4kN (763 lbf)</td>
<td>33.9kN (7.63 klbf)</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>265</td>
<td>3kN (678 lbf)</td>
<td>6kN (1.36 klbf)</td>
<td>60.3kN (13.56 klbf)</td>
</tr>
<tr>
<td>125</td>
<td>125</td>
<td>335</td>
<td>4.7kN (1.06 klbf)</td>
<td>9.4kN (2.12 klbf)</td>
<td>94.3 kN (21.19 klbf)</td>
</tr>
<tr>
<td>150</td>
<td>150</td>
<td>380</td>
<td>6.8kN (1.53 klbf)</td>
<td>13.6kN (3.05 klbf)</td>
<td>135.7kN (30.51 klbf)</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
<td>450</td>
<td>12.1 kN (2.71 klbf)</td>
<td>24.1kN (5.42 klbf)</td>
<td>241.3kN (54.24 klbf)</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>600</td>
<td>27.1kN (6.10 klbf)</td>
<td>54.3kN (12.20 klbf)</td>
<td>542.9kN (122 klbf)</td>
</tr>
<tr>
<td>400</td>
<td>400</td>
<td>800</td>
<td>48.3kN (10.85 klbf)</td>
<td>96.5kN (21.70 klbf)</td>
<td>965.1kN (217 klbf)</td>
</tr>
<tr>
<td>500</td>
<td>500</td>
<td>1000</td>
<td>75.4kN (16.96 klbf)</td>
<td>150.8kN (33.9 klbf)</td>
<td>1,508kN (339 klbf)</td>
</tr>
</tbody>
</table>
PREPARE THE PEDESTALS FOR INSTALLATION

- Remove the pedestal and cartridge tops as shown below.

REMOVE FROM ASSEMBLY BEFORE INSTALLING SHAFT.
(NOTE MATCH MARK POSITION ON PARTS FOR REFERENCE DURING REASSEMBLY)

PARTS ARE ATTACHED TO LOWER BEARINGS WITH AIR TUBING. EITHER REMOVE THE TUBES OR DRAPE THE PARTS OUT OF THE WAY WHEN INSTALLING THE SHAFT.

BE CAREFUL NOT TO CHIP OR DAMAGE THE CARBON WHEN HANDLING.
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Radial Gas Bearings – Assembly

- Place the pedestal tops into position. Ensure that the match marks are correct when assembling.
- There will be an intentional gap between the upper and lower pedestal components. Tighten the pedestal retaining screws to 12 ft./lbs.
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Radial Gas Bearings – Application: Rotor Refurb – Protecting Journals
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Radial Gas Bearings – Application: Gas Bearings for Balancing Operations

- Eliminates marking on journals
- Hard or Soft balancing
- Slow speed and high speed balancing

Patent Pending
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Externally-Pressurized Gas Thrust Bearings
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Externally-Pressurized Gas Thrust Bearings

Patent Pending
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Externally-Pressurized Gas Thrust Bearings – Integral with Radial Bearing

- Attach the axial bearing adapter plate to the bearing cartridge assembly using the adapter plate mounting screws.
- Slide the axial bearing assembly onto the shaft until it hits the adapter plate. Insure the input air ports are oriented as desired and loosely install the axial bearing assembly mounting screws.
- Turn on the air pressure to the bearings and slide the shaft towards the axial bearing assembly until it contacts the runner. Turn the air off.
- Loosely attach the axial bearing retention parts to the shaft then turn the air on and fully tighten the retention parts. Turn the air off when complete.
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Externally-Pressurized Gas Bearings as Seals

ZERO FRICITION
EASY TO USE
HIGH PERFORMANCE
SILENT AND SMOOTH

NEWWAY®

air bearings
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings as Seals – Flow into Hydrodynamic vs Hydrostatic Gap

<table>
<thead>
<tr>
<th>AERODYNAMIC</th>
<th>AEROSTATIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Choked Flow – No Adjustability)</td>
<td>(Free Flow – Adjustable)</td>
</tr>
</tbody>
</table>

**THE FLOW INTO THE GAP MUST COME THROUGH THE EDGE AREA OF 2MM. SQ.**

**THE FLOW INTO THE GAP BLEEDS THROUGH THE WHOLE FACE AREA OF 14568MM. SQ.**

**183.6 OD**

**123.2 ID**

**1.7MM. SQ.**

**.003 MM GAP**

**14568MM. SQ.**

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*NEWWAY* air bearings
Externally Pressurized Gas Bearings for Use in Rotating Equipment
Gas Bearings as Seals – Double-Opposed Gas Bearing Seal Faces

US 8,753,014
Externally Pressurized Gas Bearings for Use in Rotating Equipment
Gas Bearings as Seals – Circumferential Seal
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings as Seals

Porous gas bearing seal designed as a double opposed isolation seal in a very compact package. It can completely contain 30 psi with 0.5 SCFM of barrier gas @ 45 psi.

US 8,753,014
Externally Pressurized Gas Bearings for Use in Rotating Equipment

Gas Bearings as Seals – Key Take-aways

1. Combine sealing and bearing functionality
2. Operate at the most extreme temperatures
3. Do so using the process gas in the bearing gap
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Gas Bearings as Seals – Other Attributes

- External Pressurization Allows Frozen Seal Faces to Pop Open Before Rotation
- Pressure evenly distributed across seal face, maintaining laminar flow for less heat production
- Thrust bearing can become the primary seal face
- Very low flow
Externally Pressurized Gas Bearings for Use in Rotating Equipment

To obtain additional information on Externally-Pressurized Gas Bearings....

- Visit www.NewWayAirBearings.com
- Contact
  - Drew Devitt - CTO New Way Air Bearings
devitt@newwayairbearings.com
  - Rick Pollick - Director, New Business Dev. New Way Air Bearings
pollick@newwayairbearings.com