Choosing Magnetic Bearing Technology for Improved Performance

Kaitlin Logan
February 28, 2019
Agenda

• Magnetic bearing background
• Core magnetic bearing benefits
• University of Texas at Austin background
• System performance
• Additional magnetic bearing benefits
History of Magnetic Bearing Technology

- First patents came during WWII
- Magnetic bearing technology introduced in 1998 on critical naval applications
- Introduced in commercial HVAC in 2002
- Bearings support load using magnetic levitation
Bearing Options for Centrifugal Chillers

OIL-LUBRICATED BEARINGS

REFRIGERANT-LUBRICATED BALL BEARINGS

MAGNETIC BEARINGS
Magnetic Driveline Benefits

Single moving assembly suspended in a magnetic field with no lubrication system
• 80% fewer moving parts
• Non-contact design

Magnetic bearings deliver
• Extraordinary efficiency & wide operating map
• Superior durability
• Simplified maintenance

Enhanced longevity & reduced maintenance!
Highly Engineered Technology Offers Simplicity

- Highly complex design – behind the scenes
- Magnetic bearing controller is measuring and responding 20,000 times per second

One mil is $= \frac{1}{1000}$ th of an inch
$= 0.025$ mm
$= “less \ than \ the \ width \ of \ a \ human \ hair”$

Sensing position down to hundredth of a mil and correcting position to remain centered
During a power failure

- An uninterruptable power supply (UPS) provides power to the bearings until rotation has stopped
- Additional backup bearings provide protection if power AND the UPS fail
Normal Chiller Operation
Magnetic Bearing Comparison During Normal Chiller Conditions and Surge

Legend:
- Radial J Bearing
- Radial K Bearing
- Thrust H Bearing
Magnetic Bearings Provide a Wide Operating Range

The operating map can vary, please contact your local sales representative for project specific details.
Case Study Site – University of Texas at Austin

About UT

• Opened its doors in 1838 and employs over 20,000 Staff and serves over 51,000 students.

• Despite incredible growth in both served pace and energy output, carbon emissions are equivalent to 1976 levels due to efficiency improvements in both demand at the buildings and supply at the power and chiller plants.

Pickle Research Campus

• Developed in 1949 to perform research in the areas of defense, high speed computing, nuclear physics, and space flight.

• Separate from main campus cooling loop.
Upgrading of Facilities

- Cooling Tower System
- Chiller
- Controls
Upgrading Chiller System

Old System:
- 2 centrifugal chillers using R-11
- 600 tons and 200 tons
- Constant speed, oil-lubricated bearings
- Minimum entering condenser water temperature: 65°F

Upgraded System:
- 1 centrifugal chiller using R-1233zd
- 300 ton machine
- Variable speed drive, magnetic bearings
- Minimum entering condenser water temperature: 40°F

Upgraded System online May 2018

Magnetic bearing chiller installed in West Pickle Research Center mechanical room
Focus around Real World Performance

300 Ton Magnetic Bearing Chiller
- 12 foot shells
- Retrofit installation occurred in 1 piece
- Active filtered VSD to meet intent of IEEE

• Machine design to allow for wide operating map
• Improved performance at reduced load and lift

Data Collection:
• Start-up in May
• Data collection in 15-minute intervals using UTA BAS system

---

Partload Data (Minimum Condenser Water Temperature)

<table>
<thead>
<tr>
<th>CEFT (°F)</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>65.00°</td>
<td>0.5489</td>
<td>0.5399</td>
<td>0.5413</td>
<td>0.5519</td>
<td>0.5682</td>
<td>0.5937</td>
<td>0.5795</td>
<td>0.5621</td>
<td>0.5261</td>
<td>0.4691</td>
</tr>
<tr>
<td>80.00°</td>
<td>0.4731</td>
<td>0.4692</td>
<td>0.4710</td>
<td>0.4806</td>
<td>0.4943</td>
<td>0.5125</td>
<td>0.5407</td>
<td>0.5047</td>
<td>0.4576</td>
<td>0.4086</td>
</tr>
<tr>
<td>75.00°</td>
<td>0.4287</td>
<td>0.4210</td>
<td>0.4188</td>
<td>0.4198</td>
<td>0.4252</td>
<td>0.4340</td>
<td>0.4553</td>
<td>0.5024</td>
<td>0.5171</td>
<td>0.5221</td>
</tr>
<tr>
<td>70.00°</td>
<td>0.3821</td>
<td>0.3719</td>
<td>0.3608</td>
<td>0.3551</td>
<td>0.3542</td>
<td>0.3594</td>
<td>0.3742</td>
<td>0.4086</td>
<td>0.4994</td>
<td>0.7560</td>
</tr>
<tr>
<td>65.00°</td>
<td>0.3320</td>
<td>0.3184</td>
<td>0.3062</td>
<td>0.3004</td>
<td>0.2999</td>
<td>0.3033</td>
<td>0.3093</td>
<td>0.3313</td>
<td>0.3906</td>
<td>0.6584</td>
</tr>
<tr>
<td>60.00°</td>
<td>0.2855</td>
<td>0.2708</td>
<td>0.2594</td>
<td>0.2504</td>
<td>0.2470</td>
<td>0.2455</td>
<td>0.2492</td>
<td>0.2535</td>
<td>0.3004</td>
<td>0.5202</td>
</tr>
<tr>
<td>55.00°</td>
<td>0.2471</td>
<td>0.2299</td>
<td>0.2174</td>
<td>0.2098</td>
<td>0.2004</td>
<td>0.1998</td>
<td>0.2004</td>
<td>0.2070</td>
<td>0.2341</td>
<td>0.3774</td>
</tr>
<tr>
<td>50.00°</td>
<td>0.2069</td>
<td>0.1914</td>
<td>0.1762</td>
<td>0.1667</td>
<td>0.1587</td>
<td>0.1531</td>
<td>0.1495</td>
<td>0.1537</td>
<td>0.1742</td>
<td>0.2611</td>
</tr>
<tr>
<td>45.00°</td>
<td>0.1749</td>
<td>0.1612</td>
<td>0.1485</td>
<td>0.1335</td>
<td>0.1205</td>
<td>0.1070</td>
<td>0.1018</td>
<td>0.1152</td>
<td>0.1430</td>
<td>0.2305</td>
</tr>
<tr>
<td>40.00°</td>
<td>0.1717</td>
<td>0.1581</td>
<td>0.1456</td>
<td>0.1298</td>
<td>0.1149</td>
<td>0.1005</td>
<td>0.1032</td>
<td>0.1203</td>
<td>0.1505</td>
<td>0.2485</td>
</tr>
<tr>
<td>35.00°</td>
<td>0.1684</td>
<td>0.1550</td>
<td>0.1423</td>
<td>0.1251</td>
<td>0.1093</td>
<td>0.1013</td>
<td>0.1069</td>
<td>0.1254</td>
<td>0.1580</td>
<td>0.2658</td>
</tr>
<tr>
<td>30.00°</td>
<td>0.1635</td>
<td>0.1500</td>
<td>0.1358</td>
<td>0.1174</td>
<td>0.1072</td>
<td>0.1033</td>
<td>0.1078</td>
<td>0.1262</td>
<td>0.1587</td>
<td>0.2676</td>
</tr>
<tr>
<td>25.00°</td>
<td>0.1581</td>
<td>0.1445</td>
<td>0.1289</td>
<td>0.1143</td>
<td>0.1098</td>
<td>0.1056</td>
<td>0.1089</td>
<td>0.1269</td>
<td>0.1594</td>
<td>0.2688</td>
</tr>
<tr>
<td>20.00°</td>
<td>0.1523</td>
<td>0.1385</td>
<td>0.1252</td>
<td>0.1172</td>
<td>0.1121</td>
<td>0.1079</td>
<td>0.1099</td>
<td>0.1276</td>
<td>0.1601</td>
<td>0.2598</td>
</tr>
</tbody>
</table>

*Values are in kW/Ton

Report generated in YW 19.00; color added for emphasis

- Stable Operation
- Design Efficiency
- >25% Efficiency Improvement
- >50% Efficiency Improvement
Chiller Performance through Peak Season and Off-Design

- Cooling tower able to maintain ~80°F water temperature
- Average efficiency below 0.50 kW/Ton
  - Average on campus plant is 0.67 kW/Ton including auxiliaries
- Over 700 hours below 65°F water between September and December
  - Efficiency below 0.3 kW/Ton
Low tower water temperatures happen here too!

Weather Averages (Temperatures °F)

Austin, Texas

- Southern climates can still achieve cooler tower temperatures
- Lower tower temperatures allow the system to operate more efficiently
UTA is able to take advantage of off-design conditions.

Data points taken from UTA BAS system between May and December 2018.
### Other Magnetic Bearing Benefits: Lower Driveline Maintenance

<table>
<thead>
<tr>
<th>Driveline Maintenance Tasks</th>
<th>Magnetic Bearings</th>
<th>Oil-lubricated Bearings</th>
<th>Refrigerant-lubricated Bearings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check lubricant sump &amp; temperature control operation</td>
<td>−</td>
<td>Monthly</td>
<td>Monthly</td>
</tr>
<tr>
<td>Check lubrication eductors</td>
<td>−</td>
<td>Monthly</td>
<td>Monthly</td>
</tr>
<tr>
<td>Lubricant analysis</td>
<td>−</td>
<td>Annually</td>
<td>Annually</td>
</tr>
<tr>
<td>Replace lubricant filter(s)</td>
<td>−</td>
<td>Annually</td>
<td>Annually</td>
</tr>
<tr>
<td>Vibration analysis</td>
<td>−</td>
<td></td>
<td>Quarterly</td>
</tr>
<tr>
<td>Clean refrigerant pump strainer</td>
<td>−</td>
<td></td>
<td>Monthly</td>
</tr>
<tr>
<td>Battery health test</td>
<td>Periodically</td>
<td></td>
<td>Periodically</td>
</tr>
</tbody>
</table>
Other Magnetic Bearing Benefits: Lower Driveline Maintenance

- Initial Chiller Cost
- Magnetic Bearing Chiller
- Oil-lubricated Bearing Chiller
- Refrigerant-lubricated Bearing Chiller

Cumulative Driveline Maintenance Cost vs. Years of Ownership

- 125-150% of initial chiller cost
- 110-120% of initial chiller cost
- <10% of initial chiller cost
QUESTIONS?
Broad Offering to Meet a Variety of Project Needs

Magnetic Bearing Chillers Available 165 – 1,350 Tons

Johnson Controls Table #36