Ceramic Linear Bearings

Why ceramics? More than 2 decades of ongoing research and testing prove that ceramic linear bearings:

- Maintain longer, more reliable performance;
- Reduce friction;
- Retain stiffness;
- Operate at higher temperatures; and
- Require less lubrication.

Today, PM is the first linear bearing company in the world to realize practical use of ceramic linear bearings from diverse materials in our high-precision positioning stages operating under extreme environments.

CERAMIC LINEAR BEARINGS

CERAMIC’S BENEFITS
PM engineers have developed numerous of ceramics designs. We continue to focus on solutions that incorporate the silicon nitride (Si3N4) or oxide family (Alumina Al2O3 or Zirconia ZrO2) of ceramic compounds. The selection is made on operating conditions such as speed, temperature and surface finishing. The benefits:

Lightweight
Ceramics density is about 40%-60% percent of traditional bearing steel DIN 1.3505. Because force is directly proportional to mass, the low density silicon nitride significantly reduces the starting force which is required to move the slide/stage. This enhances operations in high-dynamic applications where the reduction of the mass-moment of inertia is an ongoing issue.

High Rigidity
Ceramic ways and balls (Silicon Nitride and Alumina) have a Youngs Modulus which is about 50% higher than steel, making them an ideal linear bearing material. Especially in use in high-speed X-Y stages, as for wirebonding machines in the semiconductor industry where rigidity and precision at high speed is required.

Increase Lifespan
The lifespan of linear bearings is directly related to hardness. The most critical mechanical property of a bearing material. With an impressive Rockwell C 78, hardness, twice as hard as many bearing steels and a high compressive strength, about 5 to 7 times that of steel, silicon nitride improves wear resistance, minimizing the damaging effects of repeated surface contacts. The lifetime of ceramic bearings varies with the operating conditions.

Operation under extremely high Temperatures
The mechanical properties of ceramics do not change by extreme low (cryogenic) and extreme high temperatures - approximately 800°C which makes it very suitable for use as heat resistant material. A major problem with such high temperatures is lubrication. Oil and grease can normally be used in temperatures up to 300°C. When temperatures exceed this, solid lubricants can be used. However, solid lubricant can only be used for temperatures up to 500°C. Ceramic bearings can operate at temperatures up to 800°C, exceeding the best high temperature bearing steels by a factor of three.

Other characteristics such as vacuum compatibility, less particle generation about 1/3 in both air and vacuum compared with stainless steel, chemically inert, corrosion resistant and electrical non-conductivity can enhance linear bearing performance in special applications. PM engineers can provide customer-focused bearing recommendations for your challenging applications.

Lifespan with zero Lube
As ceramics are extremely hard and have outstanding wear resistance, they can outperform other materials in bearing life without lubrication. Results of an lifespan test of steel and all-ceramic linear bearings without lubrication are presented in figure 2.

CERAMIC LINEAR BEARINGS

BENEFITS at a GLANCE
Non-magnetic
Vacuum compatible
High temperature
Reduced weights
Reduced Wear > Longer life
Corrosion resistant
Lower thermal expansion

APPLICATIONS
Spectroscopy
C-beamlines
Lithography
Wirebonding
X-ray equipment

Ceramic material properties according to DIN EN 12212

Table 1. Characteristics ceramics vs. bearing steel

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Si₃N₄</th>
<th>Al₂O₃</th>
<th>ZrO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>2.32</td>
<td>3.8</td>
<td>5.6</td>
</tr>
<tr>
<td>Hardness (Hv)</td>
<td>196</td>
<td>134</td>
<td>120</td>
</tr>
<tr>
<td>Young’s modulus (GPa)</td>
<td>230</td>
<td>350</td>
<td>270</td>
</tr>
<tr>
<td>Thermal expansion coefficient (x 10⁻⁶/°C)</td>
<td>1.2</td>
<td>1.7-2.3</td>
<td>1.5-1.9</td>
</tr>
<tr>
<td>Flexural strength (MPa)</td>
<td>800</td>
<td>630</td>
<td>570</td>
</tr>
</tbody>
</table>

FIGURE 1: Ceramic Speed comparison

FIGURE 2: Lifespan test

FIGURE 3: Test results prove that ceramic linear bearings often achieve longer life, 3 to 5 times longer depending on the operating conditions.

Made to Custom Order
PM ceramic linear bearings and slides are manufactured on a made-to-order basis. In this way the ceramic bearing specifications can be matched with your system requirements such as speed, operating temperature, accuracy...

Test Data
All tests in this brochure are done with below mentioned part and operating conditions:

- Test load: 17.5 Kg.
- Speed: 25 m/min
- Travel: 40mm
- Load Capacity and Life
At the moment no standards are published by ISO or JIS regarding the static and dynamic load ratings of ceramic linear bearings.

Test results prove that ceramic linear bearings often achieve longer life, 3 to 5 times longer depending on the operating conditions.

Load Capacity and Life
The static and dynamic load ratings of ceramic linear bearings in which Si₃N₄ rolling elements are used are being studied by PM. PM is working on the assumption, which are based on material testing, that the load ratings of ceramic bearings will have the same values as for the conventional steel ones based on the friction load of silicon nitride rolling elements.

Test Data
All tests in this brochure are done with below mentioned part and operating conditions:
Superior Quality
Incorporating PM ceramic bearings into your application means that you can count on quality and reliability. Our standard rails and rolling elements are known for superior surface quality, our ceramic linear bearings are matching the same high and unexcelled quality standards.

In 2005 PM was the first manufacturer who introduced ceramic linear bearings in the market. We do not only pay attention to surface finishing but we also pay a great attention to total quality. All our shipments are 100% inspected and tested for running performance and accuracy, before they leave our factory.

Focused on Innovation
Innovation and to be the best global linear bearing manufacturer at commercial pricing is our goal. Quality and service makes PM stand apart the competition.

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