Kaydon white paper

Extend wind turbine life with pitch bearing upgrades

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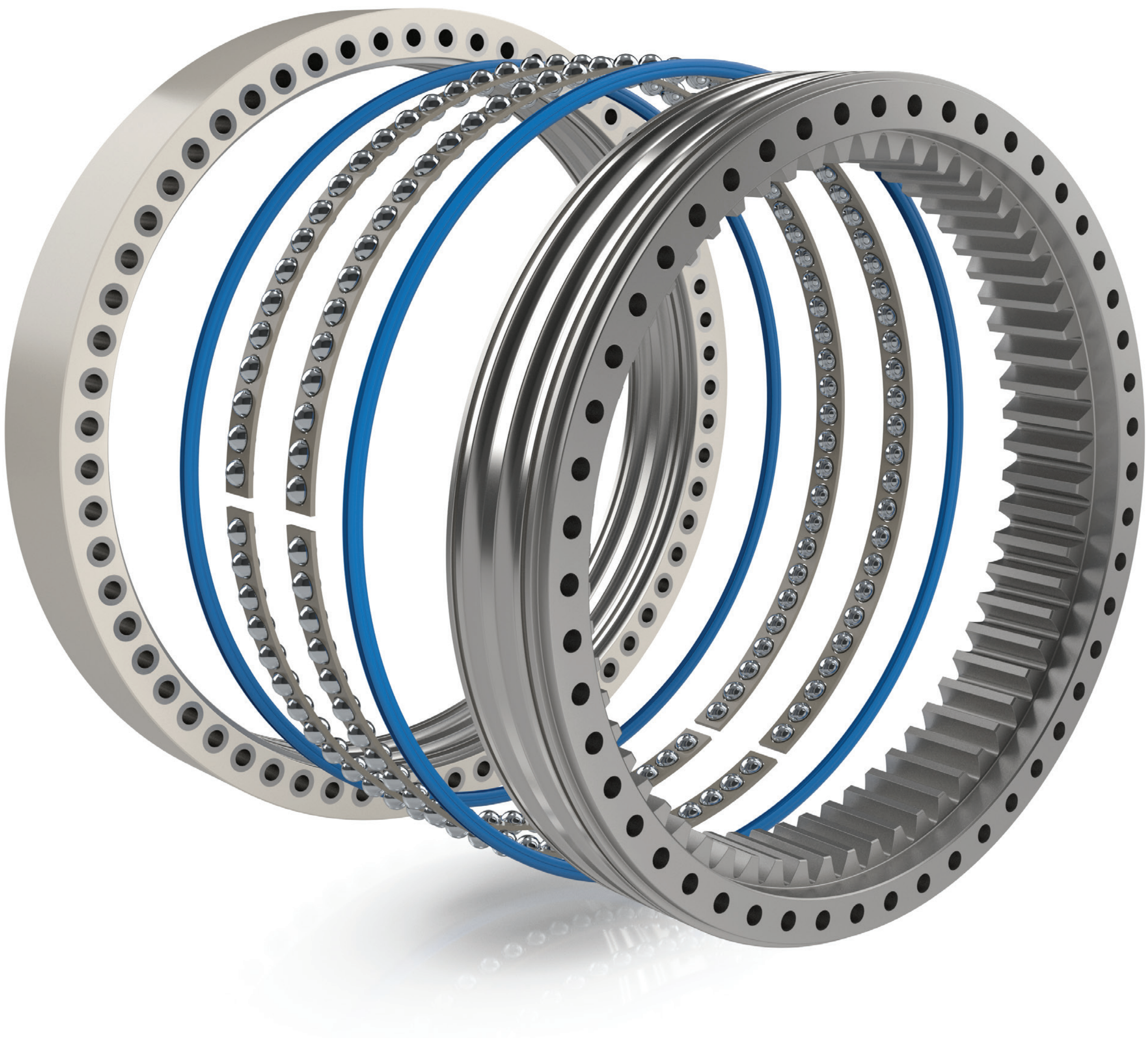

Extend wind turbine life with pitch bearing upgrades

The operational life of a wind turbine can be increased by as much as 10 years by upgrading its components and technology. A pitch bearing upgrade in particular can increase turbine life and efficiency while reducing costly downtime, all at a fraction of the cost of investing in a new turbine.

This white paper will review the defining characteristics of pitch bearings, describe the most common causes of pitch bearing failure, and outline the specific bearing improvements that can extend turbine life cycle.

What makes pitch bearings unique

Slewing pitch bearings connect the rotor hub and rotor blade, and are designed to allow the turbine blade to be indexed or positioned to optimize blade angle for the wind speed. Pitch bearings typically feature deep groove gothic arch raceways and maximum ball complement. Their single-row, four-point contact or double-row, eight-point contact designs provide exceptional load capacities, with bearing raceways that provide multiple points of contact with the balls. This enables the bearing to carry radial, thrust, and movement loads simultaneously.

Pitch bearings characteristics

- Connect blade to hub (spinner) and adjust blade angle of attack
- Rotated by internal/external spur gear or hydraulic ram
- Oscillate at very fine angles (<5°) and may never rotate more than 90° arc over life
- Stationary for long periods of time and constantly subjected to vibration
- Difficult to access; directly observed every 6-12 months during periodic maintenance
- Exposed to wide range of weather conditions
- Hollow cast iron hub and composite blade are very flexible and provide little bearing support
- Designed for 20 years (~175K hours) turbine life

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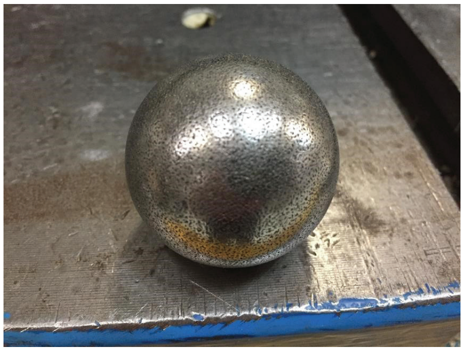
Why pitch bearings fail: **lubrication**

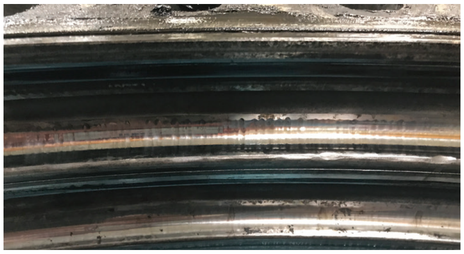
The classic failure modes predicted by standard bearing calculation models (i.e. fatigue spalling and brinelling) are actually very uncommon causes for failure. Pitch bearings typically fail for reasons related to lubricant degradation and lack of structural flexibility.

Lubrication failures

Lubrication-induced failures include vibratory wear (false brinelling), corrosion, denting, and surface-induced fatigue.

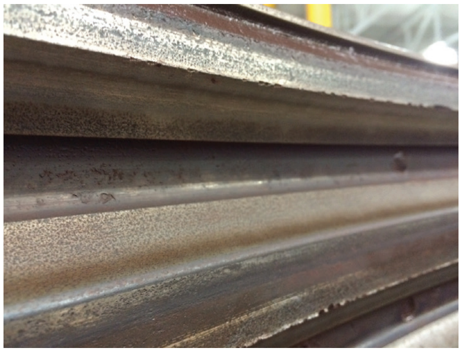


Corrosion pitting

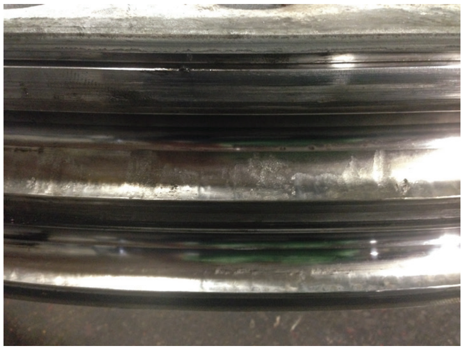


False brinelling and corrosion

Denting and corrosion



Corrosion pitting



Surface-initiated fatigue

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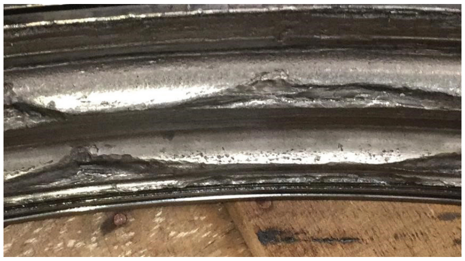
Why pitch bearings fail:
load and operation

Load failures

Load failures are directly attributable to the lack of rigid support provided by the hub and blade. Failures induced by load and operation include component fracture (rolling elements, separators, races), separator lockup, and core crushing.

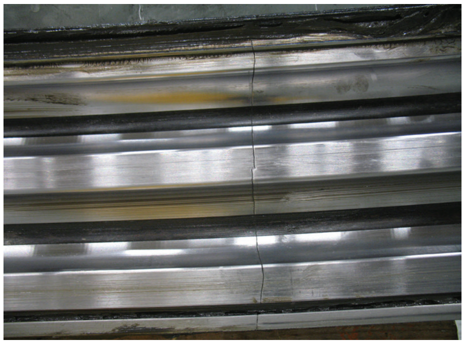
Ellipse truncation failure

In a pitch bearing, the contact area between the ball and the raceway forms an elliptical shape that is centered over the race contact angle. When the races are very thin or inadequately supported, deformation can cause the ellipse to drop off the physical raceway surface, resulting in truncation. Under severe truncation, stress can cause the ball path edges to break or the balls to fracture.

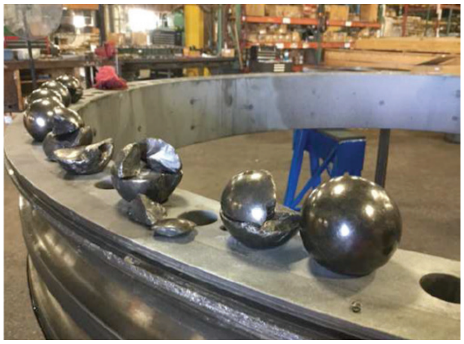


Contact truncation

Core crushing and cold working

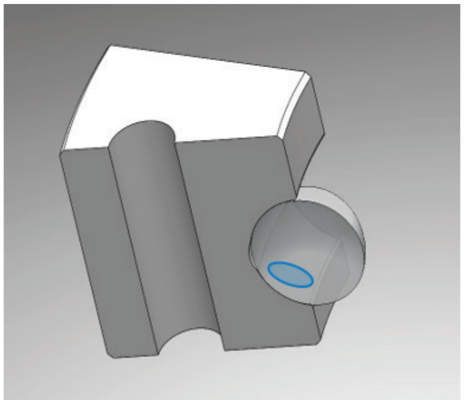


Race cracking

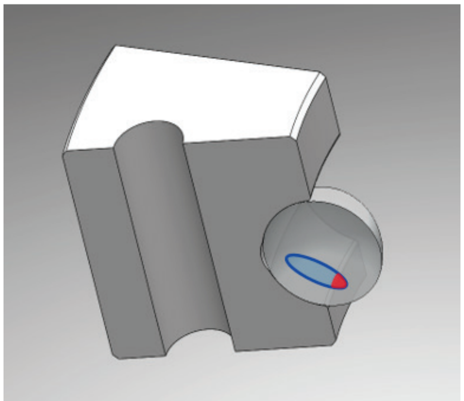


Fractured balls

Separator fracture



Elliptical shape (undamaged)



Elliptical shape (before failure)

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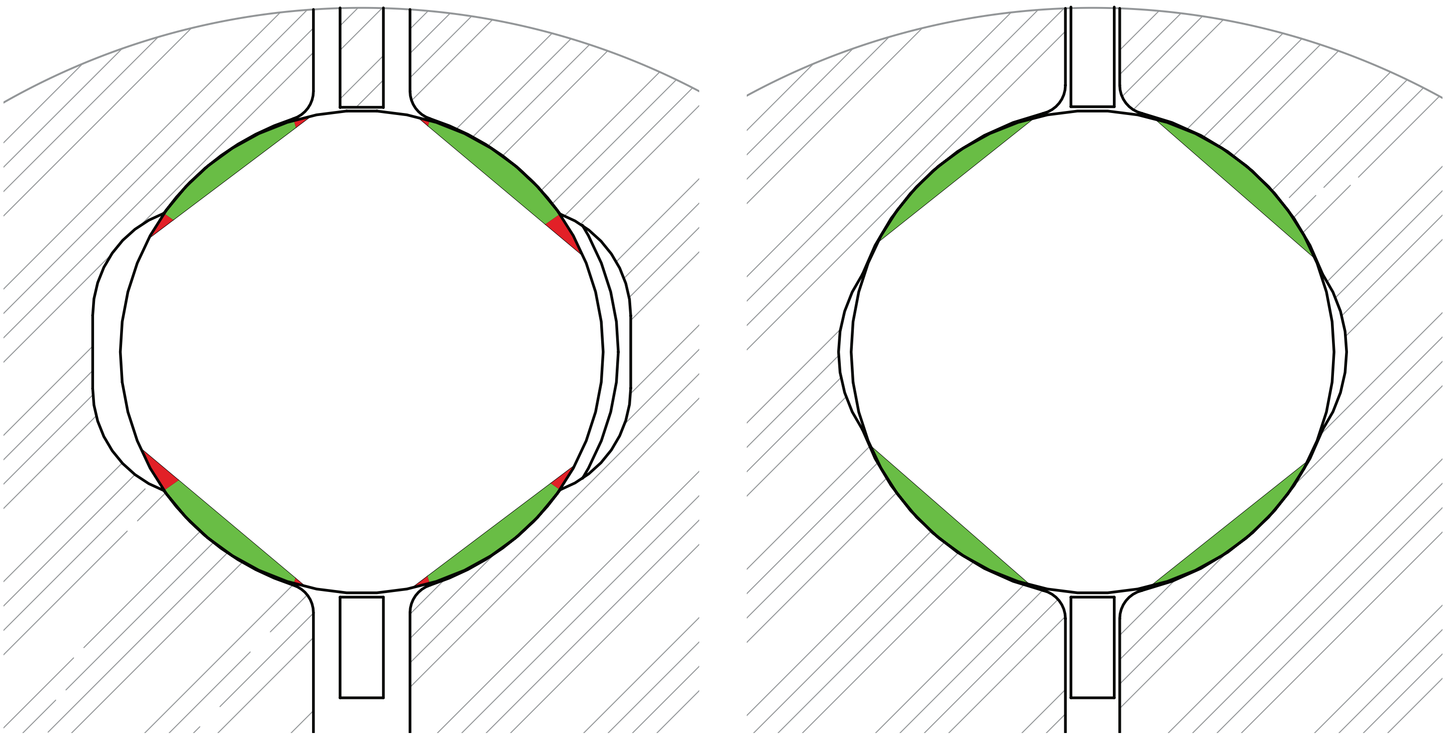
Bearing upgrade: **path surface area**

Pitch bearing upgrades are designed to address the specific failures found in a given bearing. With the potential cost of downtime and bearing change-outs running into the hundreds of thousands of dollars, it pays to find a supplier who can offer an upgrade solution that will improve productivity and extend turbine life cycle.

The most effective bearing upgrades mitigate edge loading and strengthen the races; address separator load and wear; prevent contamination; and, ultimately, result in a more efficient bearing. Depending on a given bearing's specific issues, bearing upgrades should involve some or all of the following improvements.

Path contact area

Increasing the path surface area successfully minimizes or eliminates contact truncation. The added material strengthens the rings and reduces deformation.



The contact pattern of an OEM pitch bearing (left) vs the bearing upgrade (right). Contact truncation indicated in red.

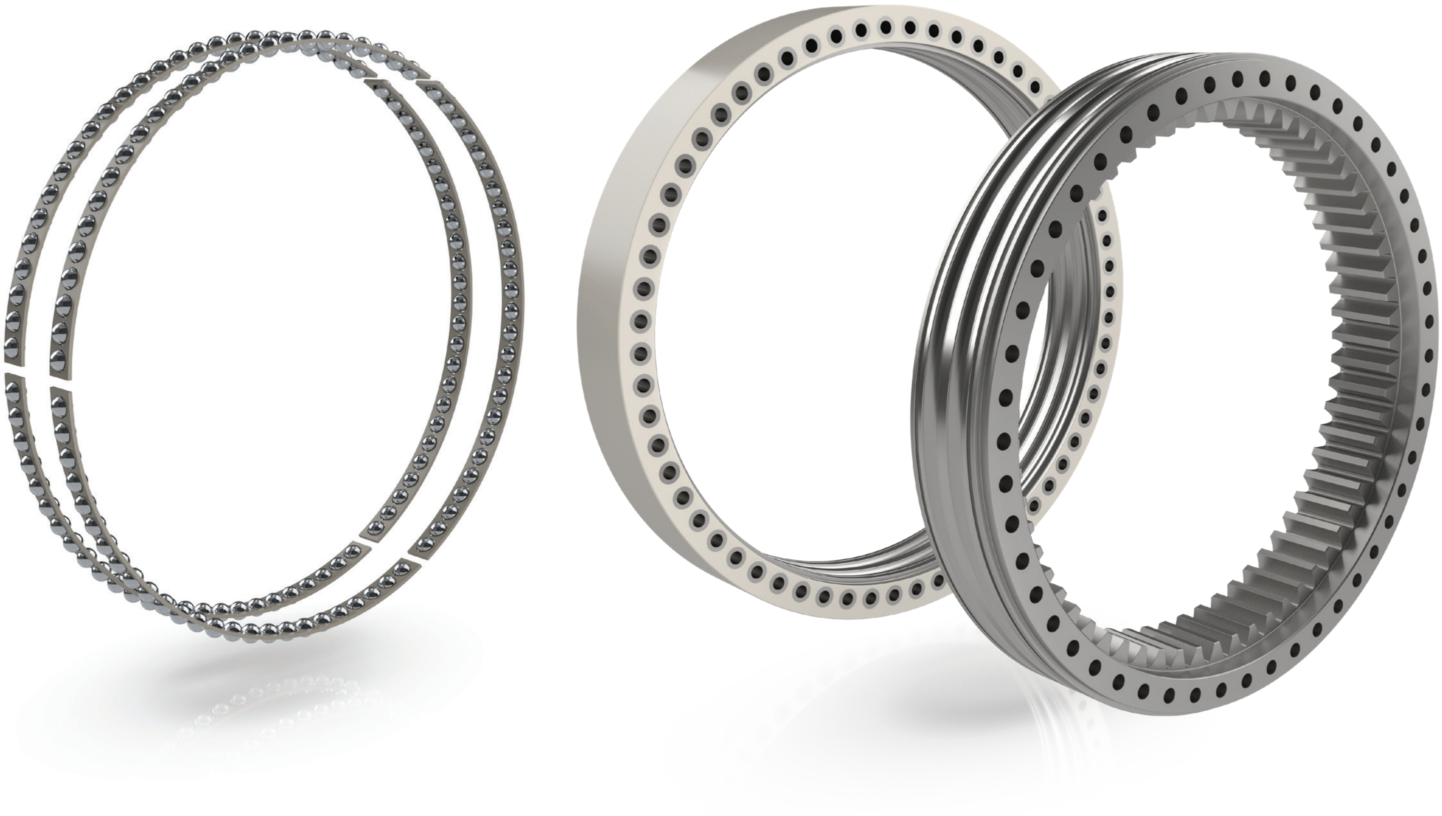
Bearing upgrade: **separator design, raceway geometry**

Separator design

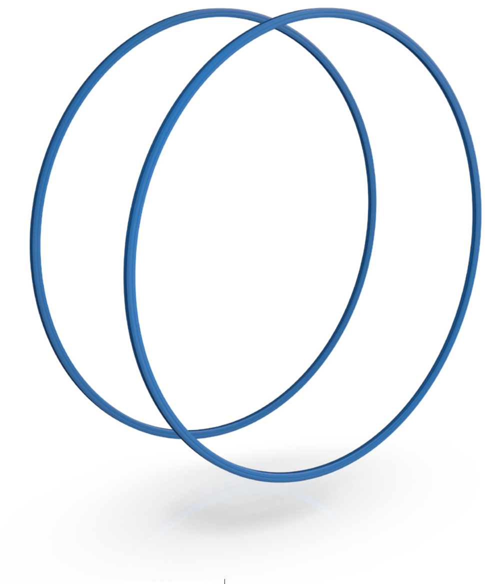
Splitting the separator ring into segments allows limited individual freedom of movement, reducing the tensile and compressive load. The use of high-strength steel alloys improves durability and reduces contact wear and abrasion.

Raceway geometry

The use of GD&T controls on path form and spacing improve load sharing and balance. A smooth path finish reduces skidding and internal friction.



Bearing upgrade: **seal design and raceway hardening**

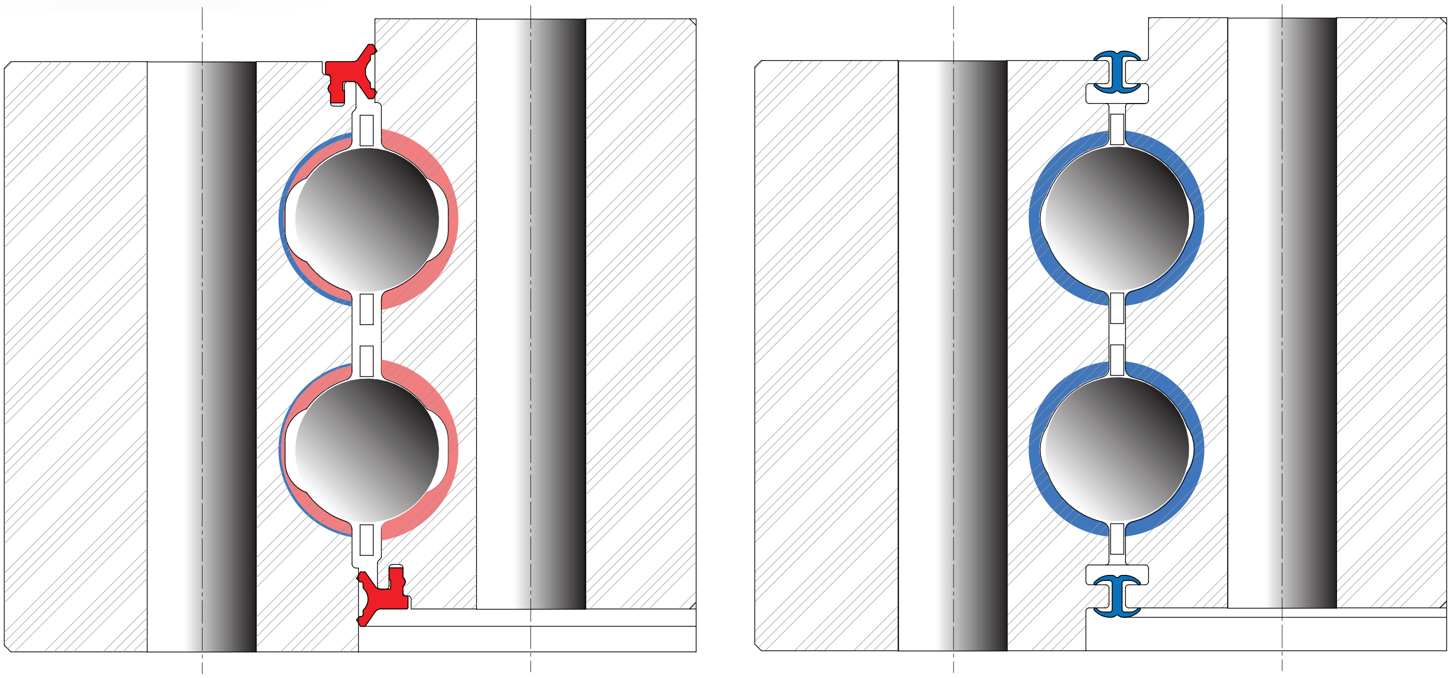


High-endurance seal design

Replacing the existing seal with an 'H' seal cross-section profile and labyrinth retention groove can prevent contamination ingress. The floating design is highly responsive, and provides seal pressure even when deformed. Wear-resistant thermoplastic polyurethane lasts longer than conventional rubber.

Raceway hardening

Assuring adequate case depth helps prevent subsurface yield or core crushing. A uniform hardness pattern along the entire path surface helps ensure the hardened layer can absorb heavy loads, even at high operating contact angles.



Recommended case depth shown in blue; actual case depth of failed bearing (left) shown in red. The failed bearing features rubber seals, which are replaced with an 'H' seal cross-section profile in the bearing upgrade (right).

Bearing upgrade: **packaging**

Proper packaging

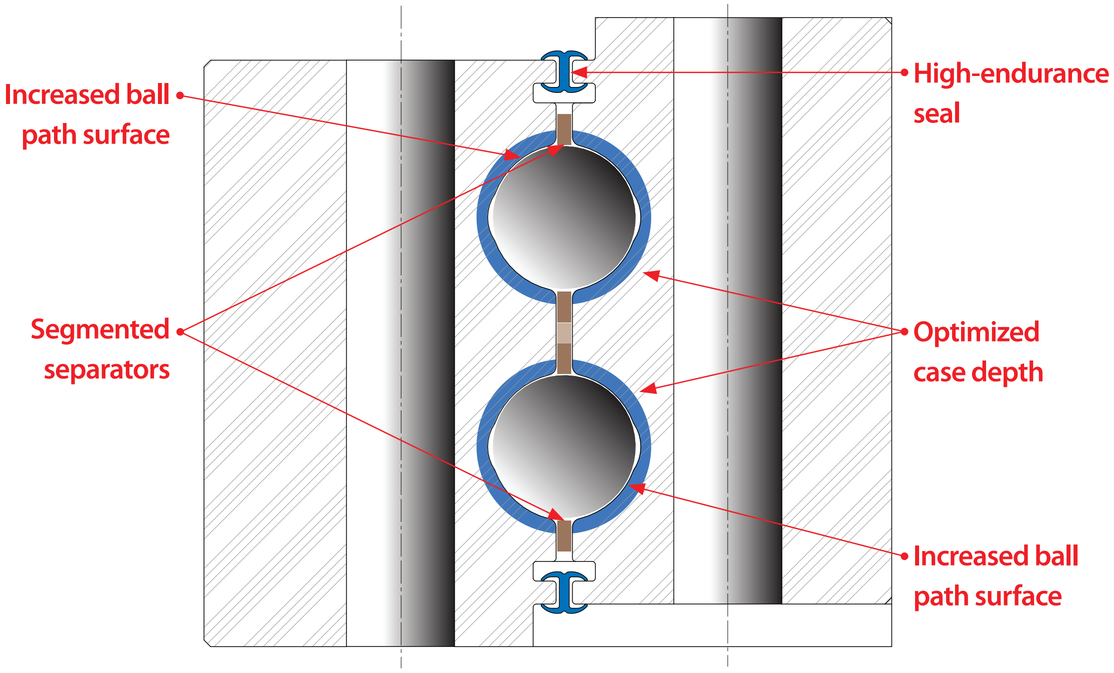
Proper packaging can prevent corrosion and damage from shock, vibration, and other hazards during transport. Packaging should include the application of a corrosion-preventative coating to mounting holes; wrapping bearings in VCI paper; packaging in vacuumed-sealed bags; and individual crating (stacked in two-high sets).

Bearing upgrades extend wind turbine life

Kaydon offers upgraded pitch bearing solutions that can increase turbine life and efficiency and reduce downtime. Upgrades can:

- mitigate edge loading and strengthen the races
- address separator load and wear
- prevent contamination ingress
- retain lubricant
- result in a better bearing

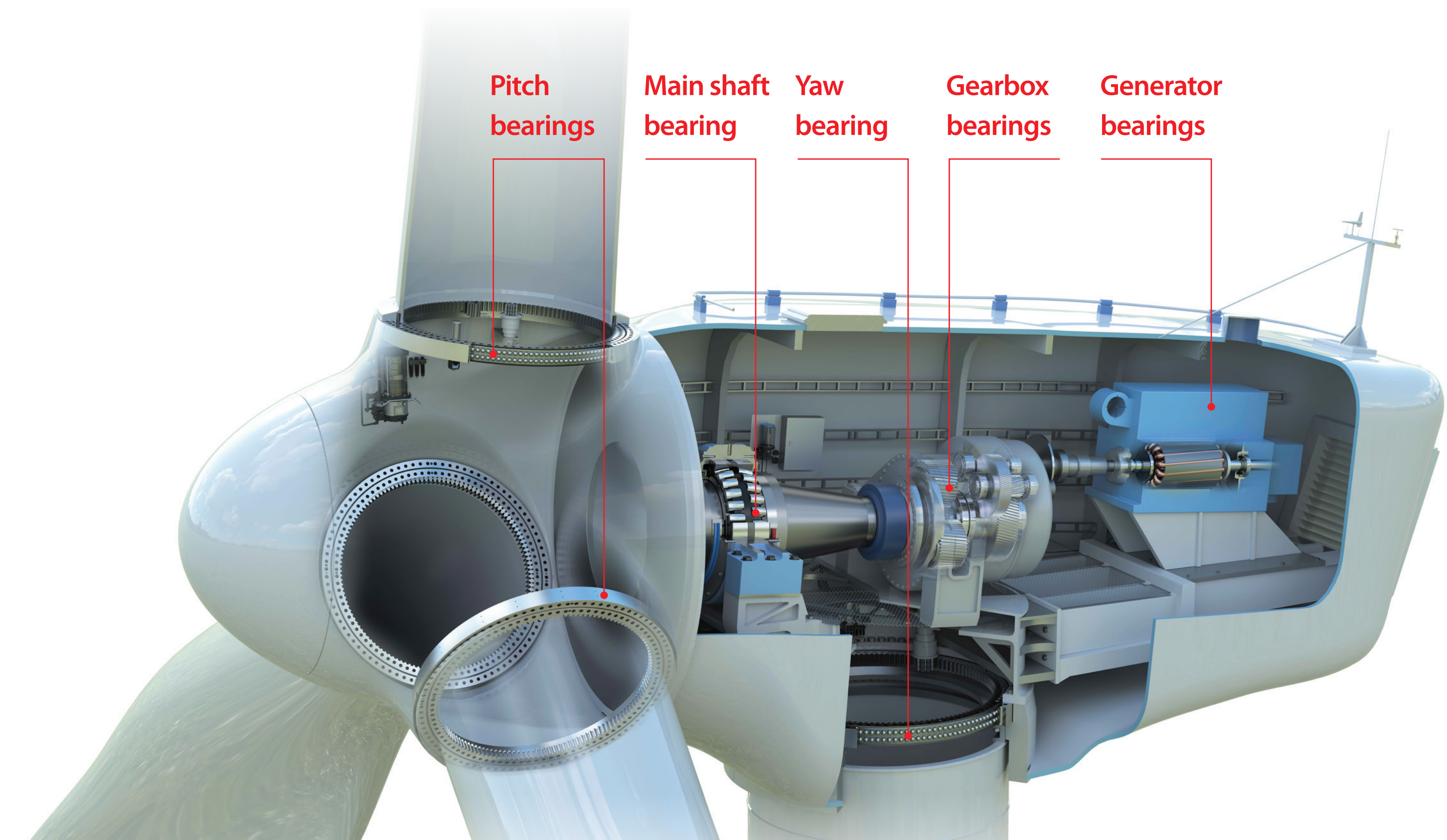
Kaydon pitch bearing upgrades



Reduce turbine life cycle costs with SKF and Kaydon

For more than 75 years, Kaydon has been designing and manufacturing slewing bearings for the most demanding applications, using best-in-class design and simulation tools. Kaydon has designed and manufactured slewing bearings for wind turbine pitch and yaw positions since the 1990s and, for the past decade, has provided aftermarket upgrades that have been proven to reduce the total life cycle cost of wind turbines.

SKF and Kaydon also offer replacement bearings for all major turbine manufacturer's designs. Additional SKF industry expertise includes lubrication, lubrication delivery, sealing, and condition monitoring systems.



Explore SKF and Kaydon's complete wind industry product portfolio with SKF Virtual Turbine, available to download from the App Store or Google Play.

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