

Technical Article

ADAPT™ Bearings:

A Field-Proven, Easier-To-Install Alternative
to Traditional Float Position Roller Bearings
on Rotating Shafts



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ADAPT™ Bearings:

A field-proven, easier-to-install alternative to traditional float position roller bearings on rotating shafts

- Extend bearing life and simplify installation in elevated temperature, high-load applications
- Unique design simultaneously handles dynamic misalignment and axial displacement
- Tested more durable than toroidal, cylindrical and other float position bearings
- Proven over years in continuous caster operation
- Promise shown in paper mill dryer rolls; ongoing evaluation of other demanding operations

Abstract

This paper explores how ADAPT™ bearings can support improved productivity in industrial applications where toroidal, self-aligning cylindrical and other roller bearing designs are commonly used in the float position on rotating shafts.

Traditional roller bearings meet most all of today's heavy industry application requirements, but where dynamic misalignment and axial displacement are a challenge, a superior bearing solution is required. The Timken® ADAPT™ bearing evolves traditional cylindrical and spherical roller bearing designs into a new concept possessing key attributes of both the **axial float ability of a cylindrical roller bearing and the misalignment capabilities of a spherical roller bearing.**

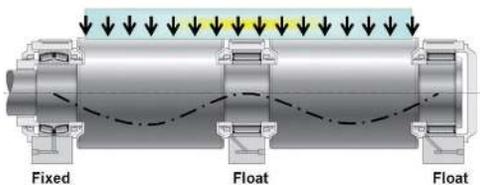
Validated by extensive testing and proven in continuous caster operations around the world, the ADAPT bearing has the further potential to extend bearing life and improve performance in paper mill rolls, gearboxes, and industrial fans and blowers among other demanding applications that experience high loads and significant thermal axial growth of the rotating shaft.

Extreme Conditions

Traditional roller bearing designs (i.e., tapered, cylindrical, spherical) meet most of today's application requirements for heavy industry. However, where dynamic misalignment (continuous misalignment of the shaft relative to the bearing during operation) and high axial displacement (movement parallel to the axis of the shaft) are encountered, a bearing that is more forgiving, more reliable, easier to mount and easier to maintain is sought after.

High-load, high-temperature applications require roller bearings specially configured for extreme environments. Use on slab support rolls in continuous casters is an example. High loads, high deflection and high thermal expansion at low rotational speeds test the limits of conventional roller bearings used in the float position (where a spherical roller bearing is typically used in the fixed position). Likewise, large steam-heated cylinders (dryer rolls) found in paper mills pose the same impediments to long, reliable bearing life. In industrial fans and blowers, and many types of gearboxes as well, heavy loading, elevated temperatures, significant temperature fluctuations and recurring shaft deflection are also constant challenges.

Figure 1



Fixed and Floating Bearing Configurations

These applications have two or more bearings supporting a rotating shaft. A single fixed-position bearing, usually a spherical roller bearing, carries the radial and axial loads and anchors the roll. The remaining positions will be floating and use toroidal, cylindrical or spherical roller bearings. When a spherical roller bearing is used, it is arranged to move axially in its housing. These positions carry only the radial load and must accommodate thermal axial growth of the shaft/roll. Figure 1 shows a typical configuration.

Spherical roller bearings perform well in the fixed position, but the float position bearings are a more complex matter. Early designs used spherical roller bearings engineered to float within their housings. While these accommodate static and dynamic misalignment, the drawback comes from the considerable axial force required to move the bearing axially while under a high radial load — this introduces high and nonuniform reactions in the bearing until thermal equilibrium (steady state) is reached.

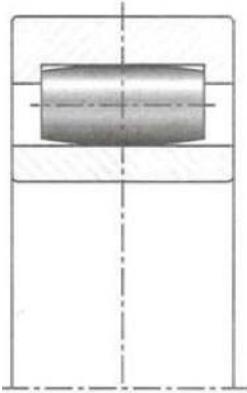


Figure 2:
Cylindrical Roller Bearing incorporated
within a spherical bushing.

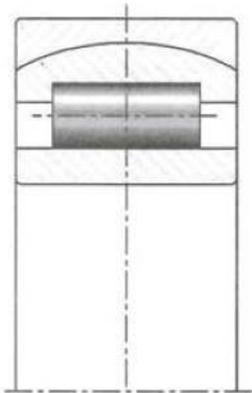


Figure 3:
Self-Aligning Cylindrical.

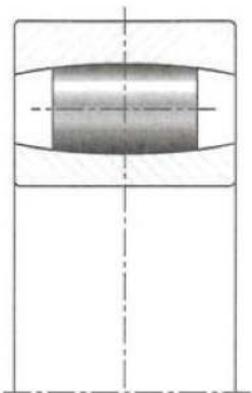


Figure 4:
Toroidal Bearings

Searching for a Solution

An improved bearing arrangement for these applications has been a target for designers and manufacturers for several years. Continuous caster applications were the original target, and the challenge was distilled down to providing a float position bearing that:

- Possesses high static and dynamic radial load within compact industry standard [ISO] dimensions
- Can accommodate shaft misalignment of +/- 0.5°
- Has internal axial-float capability of at least +/- 6 millimeters (0.25") to accommodate thermal axial growth of the shaft
- Can tolerate operation with marginal lubrication conditions that result from low rotational speed
- Is easy to install, remove and inspect

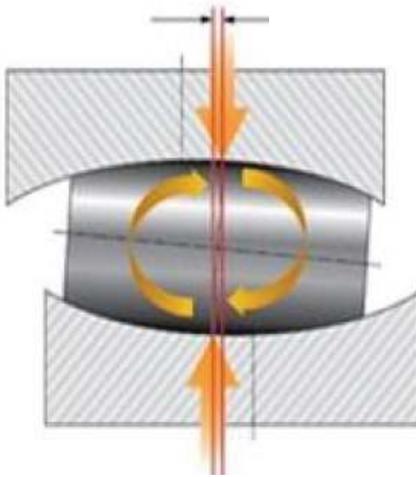
While the requirement for these attributes originated at continuous caster manufacturers and users, the same attributes can also offer benefits for other demanding industrial applications.

Several alternative caged and full-complement bearing types have been introduced in attempts to provide a better solution. The most common are cylindrical roller bearings with aggressive roller and/or raceway profiles (Figure 2), cylindrical roller bearings incorporated within a spherical bushing (Figure 3; generally termed self-aligning cylindrical or "SAC) and toroidal bearings (Figure 4).

All have achieved some measure of success but have also demonstrated limitations and drawbacks. These range from limited misalignment capability to handling and installation difficulties.

Cylindrical roller bearings with aggressive profiles can perform well in the float position in some light-duty applications but tolerate only about eight minutes (eight 60ths of one degree or 0.13 degrees) of misalignment, meaning most designs fall short of the requirements (roughly half a degree of misalignment) of heavy-duty applications.

Figure 5:



A self-aligning cylindrical roller bearing, meanwhile, is a cylindrical roller bearing inside a spherical bushing, which allows the bearing to accommodate misalignment and axial growth of the shaft. However, the addition of the spherical ring limits the radial capacity of the bearing by reducing the diameter of the rollers that can be incorporated into the predefined design envelope (smaller rollers equating to less load capacity).

The toroidal bearing is the best known and has been the prevalent design. It was introduced in the early 1990s and was first to provide combined axial float and dynamic misalignment capability. It uses highly profiled inner and outer rings and rollers to deliver this dual functionality. However, the functions are not independent of one another, and therefore, maximum misalignment cannot be achieved at the same time as maximum axial float. In addition, comparatively high radial internal clearances are required for acceptable misalignment and float performance in demanding applications.

The toroidal bearing is typically installed with an inner ring offset such that the rings become approximately aligned when the shaft reaches normal operating temperature. This means that bearing operation may be compromised during the critical warm-up period while the rings are offset. This operating condition might introduce roller skew and the potential for bearing lockup. This is illustrated in Figure 5.

In the full-complement versions of these bearings (no cage or roller retainer), there is the risk of rollers falling out during handling and installation. This can result in damaged rollers. Sometimes a snap ring is used on one side of the bearing to help retain the rollers, but extra care must be taken to correctly orient the ring at installation. Incorrect orientation can lead to the snap ring contacting the rollers in operation as the shaft expands.

Thus, the ideal bearing would combine the full axial float characteristics of a cylindrical roller bearing, the excellent static and dynamic misalignment capability of a spherical roller bearing, and a contained or unitized roller set that facilitates simple, straightforward installation and maintenance.

A Brand New Bearing

To meet increasing industry demands and customer needs, Timken engineered an entirely new bearing with a separable inner ring that simultaneously offers the float characteristics of a cylindrical roller bearing and the misalignment capabilities of a spherical roller bearing. This is the ADAPT bearing, and it is available in both caged and full-complement configurations. A key feature of the full-complement version is a roller retainer that holds the rollers together as a set during handling. This eliminates loose rollers and the risk of them falling out. In the caged version, it is the cage that provides the same roller set retention.

The Timken ADAPT bearing is specifically intended to address the limitations of existing designs. A key feature is the bearing's ability to accommodate float and misalignment independent of each other. Specifically, the bearing's axial-float position does not affect its ability to misalign and vice versa. Unlike toroidal bearings, performance is not compromised by the interaction of these two operating conditions. This is accomplished with a standard configuration of two rings and a unitized set of rollers. The basic configuration is shown in Figure 6.

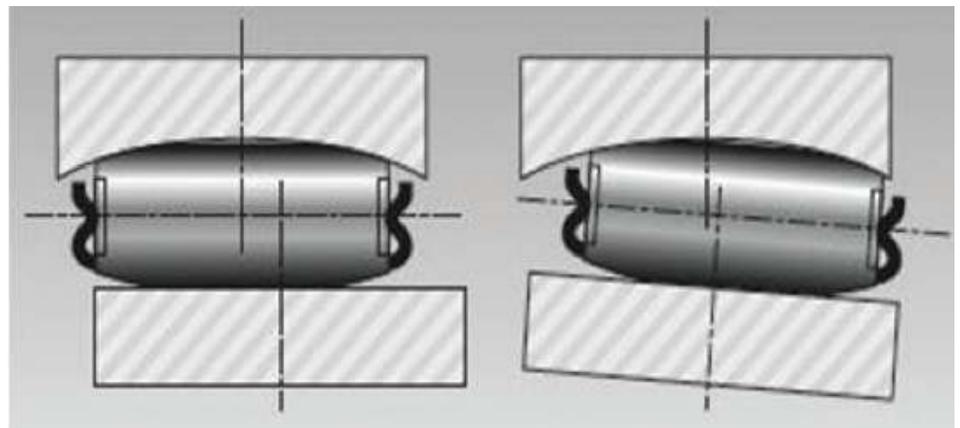


Figure 6

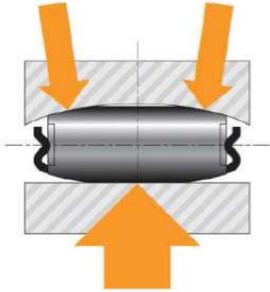


Figure 7:

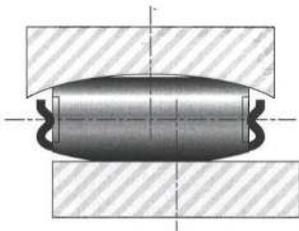


Figure 8

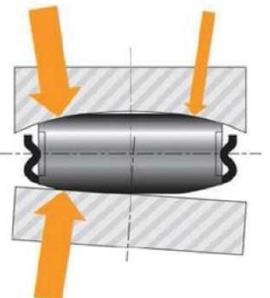


Figure 9

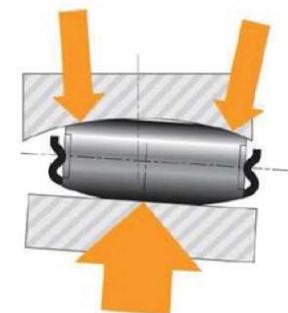


Figure 10

Bearing Design

The design of the ADAPT bearing combines a cylindrical inner ring with proprietary profiled rollers and outer ring. The combination of these profiles results in three-point contact. Specifically, the inner ring-to-roller contact occurs at a single point, while the roller-to-outer-ring contact occurs at two separate points. Thus, the outer ring contacts are symmetrically disposed at either side of the inner-ring contact, creating inherently stable roller dynamics. This is represented in Figure 7. This three-point contact also means the roller is subjected to bending when under load. To accommodate this, ADAPT bearing rollers are manufactured from case-hardened steel.

During centered and aligned operation, the loads and reactions are balanced. In Figure 8, it can be seen that significant axial movement (float) of the inner ring has no effect on load distribution. When an angular misalignment is introduced however, the initial roller to outer ring reaction becomes imbalanced. Figure 9 shows the load increasing at one end of the roller and decreasing at the other. Since the roller will always seek to balance the load, the axial component of the higher loads drives the roller over until stability is re-established as shown in Figure 10.

ADAPT bearing roller and raceway surface finishes and textures are also enhanced to maximize the load capacity and increase the relative oil film thickness (lambda ratio). The increased lambda ratio improves reliability in conditions where lubrication is marginal.

A hardened steel cage (or roller retainer in full-complement versions) was designed to unitize the roller set. This allows for separation of the three bearing components (inner ring, outer ring and roller set), which offers flexibility with procedures for installation, removal and inspection.

The full-complement design provides maximum load capacity for low-speed applications, like continuous casters, while the caged version is intended for higher speed applications.

This unique design allows the ADAPT bearing to misalign up to +/- 0.5 degrees while simultaneously handling axial displacement, regardless of the initial bearing radial internal clearance. And because radial clearance is independent of axial float and misalignment, it can be reduced, resulting in an optimized load zone (more rollers sharing the applied load). Axial float capability is a function of the inner ring width only and is not tied to the bearing's misalignment position. Where required, bearings with wide inner rings can be specified in order to further increase the axial float capability.

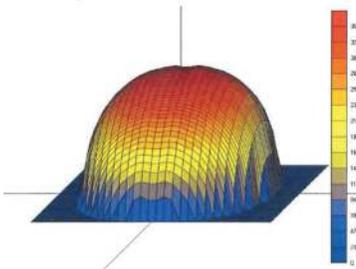


Figure 11

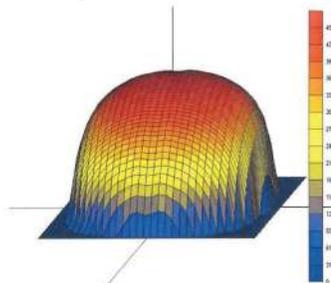


Figure 12

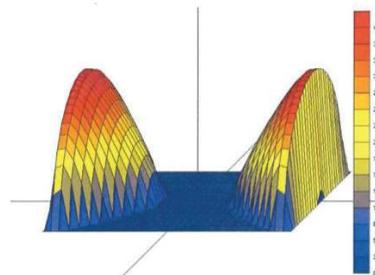


Figure 13

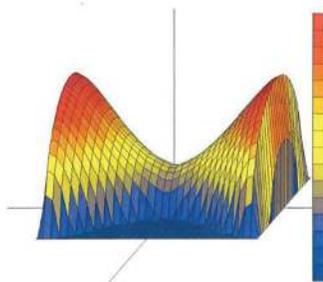


Figure 14

The separable design results in a bearing that is straightforward to install, remove and inspect. Depending on the application, the inner ring can be installed separately on a shaft while the outer assembly is installed in its housing. The inner rings are also interchangeable, so it is not necessary for users to stock matched inner and outer assemblies.

The shaft and housing design should be reviewed when designing a new installation or replacing a non-separable bearing so that appropriate housing retention on the shaft is provided when applying a separable ADAPT bearing.

Contact Stress Distribution Modeling

Timken SYBER modeling of the contact stress distribution of the ADAPT bearing shows that stress levels remain within design limits even at loads equivalent to 50 percent of the static load rating (C_0). Figures 11 and 12 show the traditional roller-to-raceway contact stress distribution at the inner ring for applied loads equivalent to 25 percent and 50 percent of the bearing's static load rating. Figures 13 and 14 show the unique distribution at the outer ring for the same loads. Note there are no edge stress spikes. As seen in Figures 13 and 14, the outer-ring contact stress distribution spreads along the roller length as the load increases. This characteristic allows optimum stress distribution and acceptable stress values to be maintained despite high applied loads.

Lubrication

Unlike cylindrical and toroidal bearings, the center section of the ADAPT bearing outer raceway is the lightest loaded, which allows the bearing to be supplied with an outer ring lubrication groove and holes when required. When this is not required and the bearing is lubricated from one side, such as in modern continuous casters, the open design of the retainer does not restrict lubricant flow. This ensures efficient lubricant distribution and purging of old grease and contaminants.

Installation

No special tooling is required to install ADAPT bearings (but is advised for many toroidal bearings to prevent damage to raceways).

Design Validation

The first prototype bearings for design validation testing were manufactured by Timken to the ISO 2212 boundary dimensions (60 & 110 x 28 mm). Heat-generation and bearing life tests were conducted. Multiple test stands were utilized with each stand incorporating two ADAPT bearings and two spherical roller bearings of the same 2212 size. The basic test stand configuration is shown in Figure 15 below.

The same configuration—but with toroidal bearings replacing the ADAPT bearings—was used for benchmarking and comparison purposes. Testing involved running the bearings through a matrix of load and speed combinations with speeds ranging from 1200 to 4800 RPM, and loads between 10 and 50 percent of the ISO calculated C1 rating. The test results showed that the design was sound. The ADAPT bearings ran cooler than the spherical roller and benchmarking bearings, used less torque, and exceeded the theoretical L10 life. These positive results allowed testing to progress to the next stage using production-sized bearings of the 4024 and 4032 sizes. Testing was now extended to include field trials in a production caster.

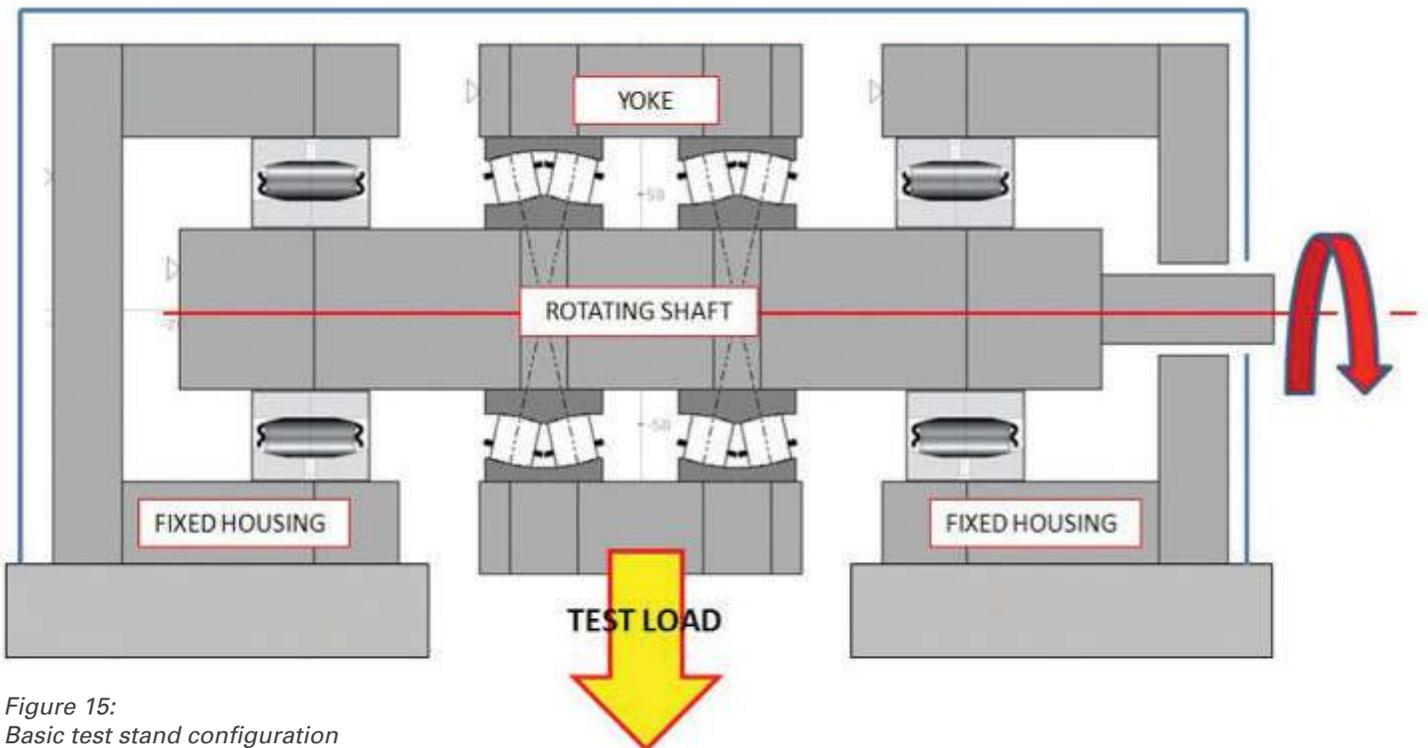


Figure 15:
Basic test stand configuration
using two ADAPT Bearings and
two spherical roller bearings.

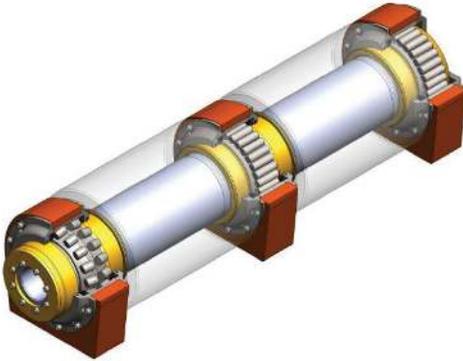


Figure 16:
Representative caster roll image
with one spherical roller bearing
and two ADAPT bearings

Success in Continuous Casters

The ADAPT bearing was presented to the Continuous Caster Division at Primetals [formerly Siemens-VAI] in Linz, Austria, and they agreed to cooperate with Timken in arranging for field trials to be carried out at a commercial production caster. The agreed bearing sizes for these trials were full-complement versions of the 4024- and 4032-size bearings that would be installed on Primetals caster roll assemblies. The specific Timken part numbers are TA4024VC4 and TA4032VC4.

The test bearings were manufactured at a production plant using standard production processes. Primetals subsequently advised that voestalpine Stahl, also of Linz, Austria, had agreed to trial the bearings on their new #6 caster. This caster was supplied by Primetals and can produce slabs up to 235 mm thick and 1,650 mm wide at speeds up to 2.0 meters per minute. The 4024 bearings were installed in a straightener segment and the 4032 bearings in a horizontal segment (Figure 16). The smaller bearings were installed first with an initial successful performance milestone of 1 million tons cast.

Heat generation, life and exaggerated misalignment testing of the same size bearings were conducted simultaneously at Timken. The heat generation and life tests were performed in a similar manner to the prototype bearings, but with different speeds and a constant load equivalent to 40 percent of the ISO calculated C1 rating. The speeds ranged up to 1600 RPM. In addition, forced misalignment testing was carried out at 0.2 degrees, 0.35 degrees and 0.5 degrees of misalignment.

Results

In-house testing of production ADAPT bearings produced similar positive results to the prototype bearings. The production ADAPT bearings ran cooler than the spherical roller bearings and exceeded theoretical L10 value by a significant margin. The cooler operation of the ADAPT bearing suggests less sliding friction within the bearing, and misalignment testing confirmed there was no roller or retainer assembly protrusion beyond the outer ring faces, up to the maximum specified misalignment of 0.5 degrees.

The TA4024VC4 bearings installed at the voestalpine Stahl caster successfully reached 1 million tons with no premature failures and remained in service for more than 3 million tons. The TA4032VC4 bearings, meanwhile, reached more than 5 million tons (exceeding initial expectations of 3.5 to 4 million tons). Subsequently, the ADAPT bearing was released for use by Primetals and voestalpine Stahl.



To date, more than 22,000 ADAPT bearings have been supplied by Timken to more than 30 casters operating in Europe, Asia and North America.

Continued Testing

Since the successful launch for continuous caster applications, ADAPT bearing testing has continued in-house for sizes up to 300 mm bore for use in a variety of industrial applications. The scope of this testing is summarized in Table 1.

Test Type	No. of Tests	Total Bearings Tested	Timken Bearings Tested	Competitor Bearings Tested	Cumulative Test Hours	Cumulative Elapsed Time (years)
Life and Durability	7	76	56	20	31,500	3.6
Performance	13	134	106	28	38,900	4.4
Application Specific Paper Dryer	1	10	8	2	1,440	0.1
	21 tests	220 bearings	170 bearings	50 bearings	71,840 hours	8.1 years

Table 1

The life and durability tests use a “first in two” method with the bearings loaded at 30 percent of their dynamic load rating and operating at approximately 30 percent of their limiting speed using a 220 cSt grade oil with a controlled inlet temperature. The monitored parameters are vibration, temperature, torque, condition and duration. Four bearing sizes have been tested to date with bores from 60 mm to 240 mm. Results have validated a load rating that is 3.5 to 7 percent greater than equivalent toroidal bearings and 30 percent longer life.

Performance testing involves operating the bearings under a variety of conditions, covering misalignment up to 0.5 degrees, four load ratios and six speeds. The monitored parameters are the same as the life and durability testing, and six bearing sizes have been tested to date. These tests have further validated performance and shown a consistent 5 to 10 percent reduction in running torque compared to equivalent toroidal bearings. The reduced running torque is a demonstration of lower sliding contact and friction within the bearing and translates to cooler operating temperatures.

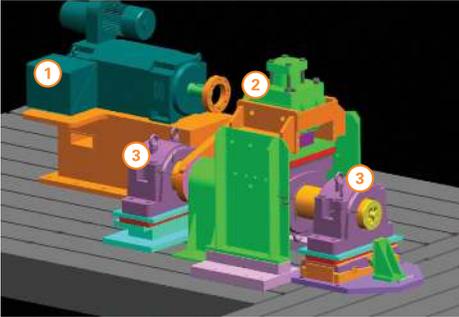


Figure 17:
 1. Drive
 2. Hydraulic Radial Load Yoke
 3. Test Bearings

Paper Mill Dryer Roll Simulation

Another test for demanding applications measures ADAPT bearings against toroidal bearings in a custom stand built to simulate the operating conditions for a paper mill dryer roll. In a modern paper mill, these rolls can be up to 2 m in diameter and 8 m long. They are subject to extreme temperature variations (and the associated axial thermal growth) as well as significant deflections — all of which must be accommodated by the bearing system.

ADAPT bearings with case carburized inner rings and caged rollers are used because of the thermal stresses developed by accelerated startups and the higher operating speeds, compared to continuous casters. The custom test stand, with the thermal enclosure removed, is illustrated in Figure 17.

Ten bearings were tested in real-world conditions, and the monitored parameters included axial force, vibration, temperature, torque and bearing condition.

Results have been favorable for the ADAPT bearing, which produced less vibration and lower operating temperatures than the competitive toroidal design. Figure 18 shows that the performance gap widens as speed increases.

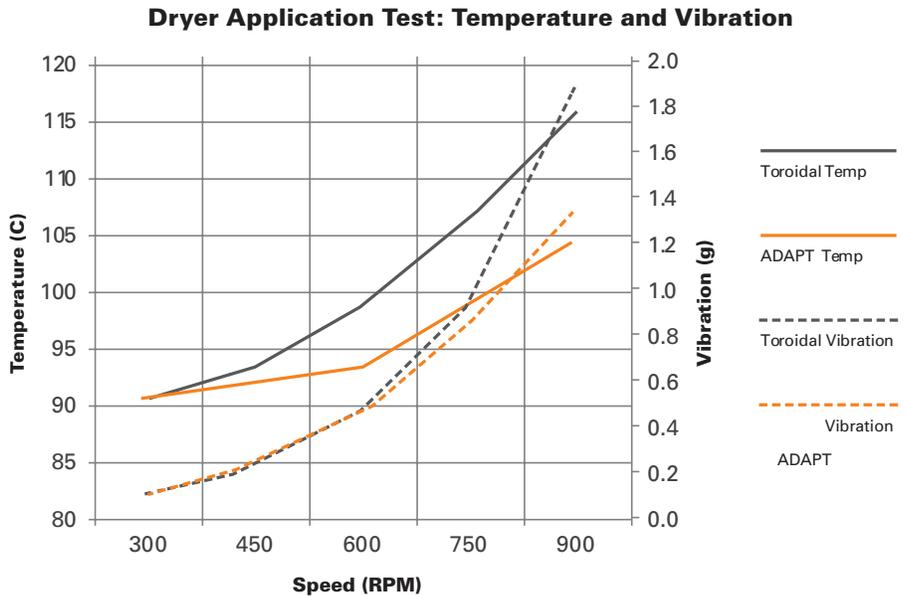


Figure 18

Conclusion

For high-load, high-temperature applications where downtime can cost tens of thousands of dollars an hour, Timken achieved its objective of producing a high-capacity bearing that simultaneously offers independent misalignment and axial-float capabilities, together with ease of installation, removal and inspection.

Timken conducted extensive in-house testing, and proven performance in production casters confirms the ADAPT bearing meets original design intent. Continued testing shows equal promise of increased capacity, lower operating temperatures, less rotational torque and longer life in paper mill dryer rolls.

Compared to equivalent-size toroidal bearings in demanding industrial operations, ADAPT bearings can offer:

- Up to 7 percent higher load rating
- 5 to 10 percent less running torque
- Operating temperatures 5 to 10° C cooler
- As much as 30 percent longer life

Moving ahead, Timken will continue to evaluate the performance of ADAPT bearings in comparable high-load, elevated-temperature applications, including wind turbines, industrial fans and blowers, and larger gearboxes.