



MEETING TODAY'S GREATER DEMANDS

John Rhodes and Karen Clever,
The Timken Company, US, explain
the need for new spherical roller
bearings to meet the needs of
tougher environments and the
increased demands of
heavy industry.

Introduction

Today, industry expectations push the limits of durability and production in heavy industry, putting traditional machine and component designs to the test. The global marketplace demands greater reliability at higher operating temperatures, loading and speeds,



Figure 1. Industry expectations push the limits of durability and production in heavy industry.



Figure 2. Timken® Spherical Roller Bearings allow for good load-carrying capacity.

emphasising increased efficiency every step of the way. For many, opportunity will come from incremental improvements to existing technologies rather than major advances.

As the cement industry faces more punishing conditions, plant and equipment operators increasingly look to suppliers and manufacturers to generate new operational efficiencies. Across industries, the goal is measurable gains in performance, productivity and profitability, resulting from improvements to existing systems, processes and assets.

Timken launched an intensive improvement effort to meet increased load, speed and temperature requirements for bearings operating in critical applications.

This paper explores new expectations for key applications, particularly in the cement industry, advances in spherical roller bearing technology, and the design and testing of Timken High-Performance Spherical Roller Bearings.

The case for spherical roller bearings

Spherical roller bearings are a special class of roller bearings, relied on in many of the most difficult, demanding applications. These self-aligning, double-row radial bearings are designed with an inner and outer ring and 'barrel' shaped rollers separated by a cage, allowing for greater load-carrying capacity and dynamic angular misalignment ability when compared to other common bearing types, including tapered and cylindrical.

Most bearings are intended to carry either a radial load (acts perpendicular to the shaft) or an axial load (also called thrust load – acts parallel to the shaft). Spherical roller bearings, however, must tolerate combined loads where moderate-to-high radial and axial forces are at work.

Spherical roller bearings are used not only where shaft misalignments are common, but where contamination, shock and vibration are also constant challenges. Their robust design and higher tolerance for misalignment is especially suited to the cement industry.

High-performance parameters

'High performance', relative to spherical roller bearings, is described as an increase in bearing service life, which offers the potential to downsize other component selections while maintaining current levels of system performance (that is, smaller equipment and systems working more efficiently/effectively; increased power density translating to greater power throughput and longer system life).

High performance is also described as a reduction in heat generation – bearings that function at lower temperatures under demanding conditions create the potential for increased efficiency and higher speeds of operation. Lower temperatures reduce the oxidation rate and deterioration of oils, greases and films, extending lubrication and thus, bearing service life.

While the basic functionality of today's spherical roller bearings remains fundamentally similar to that introduced in the 1950s, continuous improvements to performance have been a focal point for bearing manufacturers. The research and development effort from Timken progressed with the market to meet the growing size and power requirements of heavy machinery and gear-driven equipment.

Key design elements

Objectives for design optimisation of the Timken Spherical Roller Bearing included:

1. Greater load-carrying capability.
2. Reduced operating temperature.
3. Extended service life.

Specifically, activities were focused around:

1. Optimising internal geometries to maximise roller length and dynamic capacity.
2. Improving surface finishes to support higher ratings and increased lubrication lambda ratios.
3. Strengthening cage design to reduce wear.

4. Enhancing lubrication flow to rolling contact surfaces.
5. Improving heat dissipation.

As a standard element of any continuous improvement endeavor, Timken also set out to reduce design complexity where the potential for simpler and/or fewer components was presented.

The design of the new high-performance bearing follows the ISO standard for bearing boundary dimensions (Inner Diameter [I.D.], Outer Diameter [O.D.] and width), allowing for general interchangeability with other manufacturers. The standard does not, however, dictate cage design or internal geometry.

Internal geometry

At the heart of the spherical roller bearing design is the inner ring geometry, which requires precise design specification and manufacturing consistency. The inner ring allows a complex interaction between the bearing contact angle and raceway profile,¹ which must be specified to produce the most efficient raceway-roller dynamics.

Timken extended the parameters of the Timken P900 Tapered Roller Bearing to the new spherical design. The P900 relies on optimised geometries, special finishes and high-quality materials to achieve an increased power density (bearing capacity to weight ratio) and provide an efficient solution.³⁻⁵ The macro raceway profile contact geometry minimises the opportunity to develop conditions where contact stresses are concentrated at one location, thereby reducing rolling contact fatigue life.

The micro raceway texture was also improved by reducing the composite surface roughness. This has a direct effect on increasing the operating lambda (λ) ratio, where lambda equals the predicted operating oil film thickness divided by the composite surface roughness. Improvement in lambda ratio has been well documented to increase bearing fatigue life predictions, as represented by a_{3l} factor increase in factor-based life calculations.⁶⁻⁸ Specifications on micro texture were employed beyond those associated with composite roughness to ensure the desired lambda ratio is achieved in operation. The improvement in surface texture also sets the stage for potential reduced heat generation by allowing the selection of reduced viscosity lubricants that still meet adequate operating lambda ratios.

Cage construction

Cages (also called retainers) serve several purposes in the proper operation of a rolling element bearing, including separating the rolling elements to prevent roller-on-roller contact and wear. Cages also align the rolling elements on the inner ring outside the operating load zone to minimise roller sliding, skidding and skewing.

An advanced cage design methodology was incorporated into the Timken High-Performance Spherical Roller Bearing, resulting in the Timken EJ steel cage. At elevated speeds, a steel cage can provide an advantage over brass due to its lower mass and reduced roller/cage

contact. The EJ cage is also nitrided (surface hardened) for improved wear resistance and fatigue strength.

The new design incorporates many aspects of existing Timken steel cages, including inner ring piloting, low mass, low inertia, an individual cage for each row and no separate centre ring for roller axial positioning, and introduces slots in the outboard face of the cage. The symmetrical openings are oriented between the cage pockets to facilitate lubricant flow in and out of the inner ring raceway. This helps to assure lubricant availability to these rolling contact surfaces to generate a satisfactory film, while further reducing the potential for extreme heat due to viscous shear from excessive lubricant supply.

Cage guidance

The EJ design includes two independent cages (one for each row of rollers), which are assembled into an individual bearing. This allows each path of cage and rollers to operate independently. The window-style pocket construction reduces bending stresses. The cage is guided on the inner ring and runs above pitch. This increases cage stiffness and reduces stress under high shock load or acceleration.

For bearings with an O.D. greater than 400 mm, the cage and roller mass can become substantial and negatively impact bearing heat generation and operating temperatures. To counter this, the bore of larger EJ steel cage is profiled to minimise friction and associated heat generation from contact with the inner ring pilot surface.

Roller guidance

Rollers are guided by the edges of the cage pocket for smaller bearings (< 400 mm O.D.). For larger sizes, the pocket is contoured with four pads (strategically located on the bridge surface) that contact and orient the rollers coming into and out of the bearing operating load zone. This interaction minimises potential for negative roller skew and its associated increase in friction torque and operating temperature.

No central guide ring

Given these precise cage pocket interactions, a central guide ring is not required to axially position the rollers in the EJ design. Without a guide ring, the friction generated between the rollers and ring is eliminated, equating to cooler running bearings. Less friction also means less energy is needed to move the bearing initially and to keep it moving.

Eliminating the guide ring further creates extra space within the design envelope to accommodate longer rollers, meaning increased load capacity. Alternatively, lubricant flow between the roller paths is improved by increasing available void volume.

Design validation

Validation of the Timken High-Performance Spherical Roller Bearing design was extensive. It included standardised fatigue life testing to confirm durability under strenuous and accelerated operating conditions, as well as testing



Figure 3. Timken® Spherical Roller Bearings are used where shaft misalignments, contamination, shock and vibration present challenges.



Figure 4. The emphasis on increased efficiency in the global marketplace demands greater reliability at higher operating temperatures, loading and speeds.

on different platforms to verify bearing heat generation response as measured by outer ring temperature.

Methodology and modeling

Timken standard life testing is completed in a first-in-four arrangement. The bearings are tested under an elevated

load and speed condition using a circulating oil lubrication system that controls the inlet oil temperature to a specified elevated level. The intent is to test the bearing rolling contact surfaces in an accelerated manner relative to surface and subsurface fatigue modes. The influence of bearing design, material, heat treatment, geometry, surface profile and texture have a combined impact on life testing with the first-in-four format used to develop the test Weibull statistics.

Timken SYBER analytical modeling software is used to establish the predicted bearing performance based on the bearing metrology and test conditions. Test results are evaluated using Weibull statistics regarding L15.91 life and the associated 65% confidence bands to establish test performance. The Weibull result is then compared to the SYBER predictions, and an assessment is made regarding acceptability of the resultant life ratio. These ratios are reviewed to determine their degree of support for intended rating performance levels.

Validation results indicated that the Timken High-Performance Spherical Roller Bearing achieved an increased dynamic load rating of 18% and a 17% thermal speed rating increase, relative to previous Timken spherical roller bearing designs.

Conclusion

The results validate a high-performance spherical roller bearing design that could meet the escalating load, speed and temperature requirements of heavy duty industrial machines and equipment. 🌐

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