TIMKEN

Technical Article

Tapered Roller Bearing Rib-Roller End Scoring Damage

in Aircraft Landing Wheels

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Tapered Roller Bearing Rib-Roller End Scoring Damage in Aircraft Landing Wheels

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Table of Contents

Abstract

This technical paper explains the risks and root causes for rib-roller end scoring damage to aircraft landing wheel tapered roller bearings. It explains rib-roller end scoring damage, how to identify it and prevention strategies. The paper also discusses the results of Timken application testing that associated loss of grease and high preloads settings with scoring damage risk.

I. Aircraft Landing Wheel Tapered Roller Bearing Rib-Roller End Scoring Damage: You Can Help Prevent Severe Bearing Damage

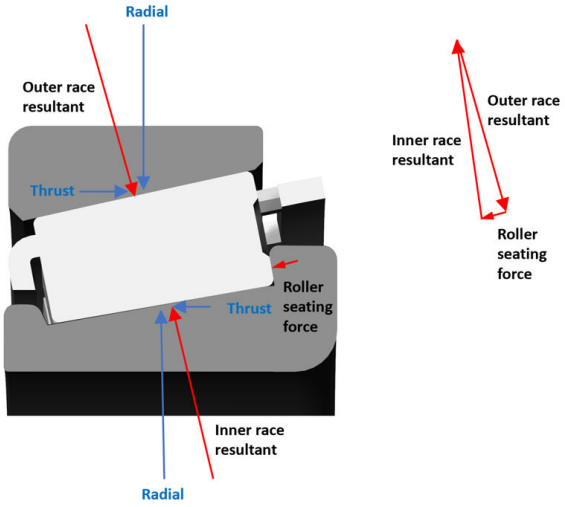
Timken works with wheel and brake manufacturers to engineer premium tapered roller bearing solutions in demanding applications like aircraft landing wheels. With nearly 100 years of manufacturing and design experience in this market space, Timken technical expertise is a vital resource for wheel and brake manufacturers worldwide.

To meet the performance needed for our customers demanding aircraft wheel applications, Timken developed the performance code 629 tapered roller bearing for aircraft landing wheels. These TRBs are designed with special features to address common damage modes like rib-roller end scoring damage that may result from improper lubrication or due to extreme operating conditions.

Integration of these special bearing features with a robust wheel and brake inspection and maintenance program are two critical elements for early detection of scoring damage and removal of damaged cone assemblies from service to ensure safe operation. Scored roller ends (explained in more detail later in this document) generate friction and heat, increasing operating temperatures that can result in grease degradation, system debris, and accelerated secondary bearing damage modes. If not properly identified during preventative maintenance, extended service could result in system damage and eventually result in the bearings to lock up.

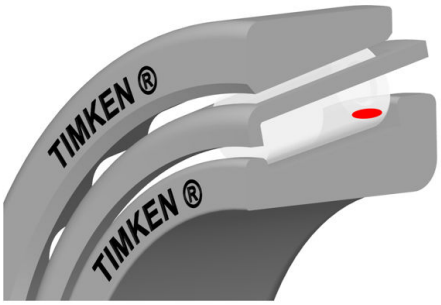
Locked Up Tapered Roller Bearing Cone Assembly

II. Tapered Roller Bearing Rib-Roller Contact Aligns the Rollers

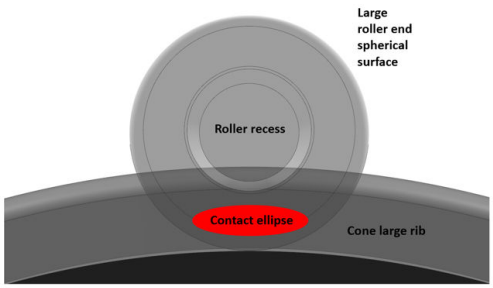


Seating Force Caused By Tapered Roller Angle

A key aspect of tapered roller bearing performance is the rib-roller end contact surface. This contact aligns the rollers on the cone race, ensuring that the rollers roll with minimal skewing and sliding. The roller seating force on the cone large rib is caused by the resultant forces from the inner (cone) race and outer (cup) race on the roller.



Tapered Roller Bearing



Rib-Roller End Contact Ellipse

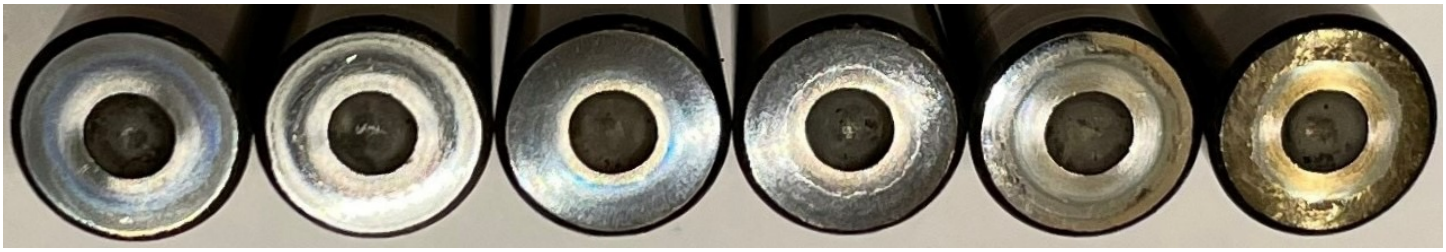
The large end of tapered roller bearing rollers have a spherical shape, which rides on the cone large rib. An optimally designed tapered roller bearing features a contact ellipse that minimizes roller skewing and contact stresses, while limiting friction-induced heat generation.

III. Scoring Damage Progression

Aircraft landing wheels are among the most challenging bearing applications due to the heavy axial and radial wheel loads, sudden accelerations, extreme temperatures, and corrosive environments. Timken's advice for proper bearing inspection and maintenance is an essential element in identifying damaged bearings before the damage progresses and becomes a safety issue.

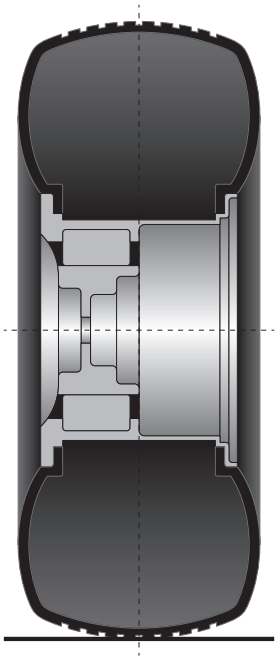
Scoring can be difficult to identify because the early indications can be subtle and varied in appearance. Here are some images of roller ends with scoring damage. Note that the scoring damage can progress slowly, resulting in various appearances depending on the severity of the damage. Scoring damage initially appears as fishhook-shaped scratches and progresses to the heavily scuffed appearance seen on the roller end on the right.

Fishhook Scratches

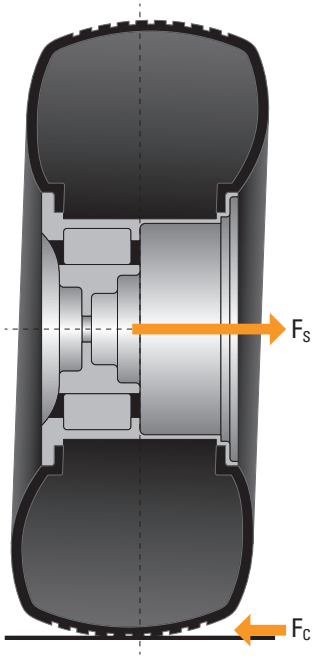


Progression of Roller End Scoring Damage

Severe Roller End Scoring Damage



Cross Section of Aircraft Landing Wheel – No Load



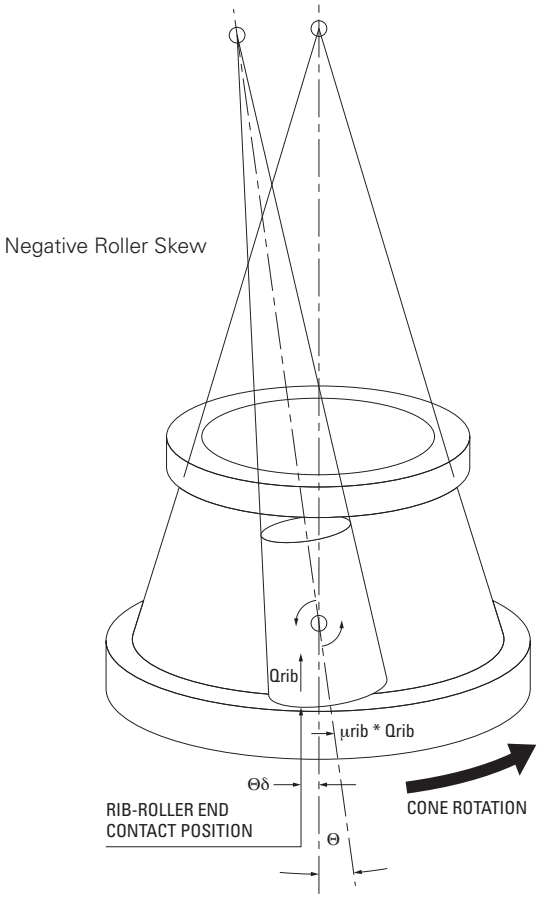
Cross Section of Aircraft Landing Wheel – Wheel Axial Load

IV. Timken Aircraft Landing Wheel Bearing Scoring Damage Tests

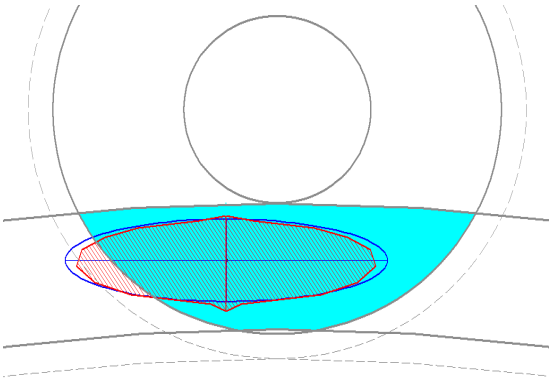
To help further the industry's understanding of the causes and solutions for rib-roller end scoring damage, The Timken Company recently completed application rig testing modeled on a main landing wheel bearing that had a history of inboard bearing rib-roller end scoring damage.

The most likely cause for scoring damage is slower speed taxi maneuvers with aggressively sharp turns. This produces high axial loads and moments that cause the rollers to skew.

Roller skewing is a dynamic condition where the roller tilts relative to the bearing centerline. Negative roller skew results in contact ellipse truncation, a condition where the contact ellipse shifts away from the available contact area and is no longer a complete elliptical shape. The negative skewing and truncation in the presence of high Hertzian rib stresses (above 40 KSI) can lead to rib-roller end scoring damage. Positive skewing can occur when the axial load is reversed and is not considered a risk factor for scoring damage.

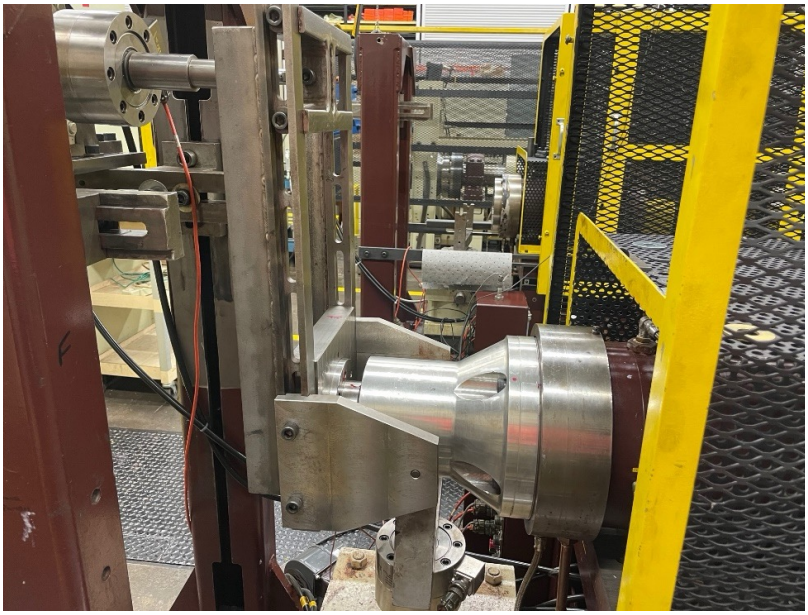


The test conditions were determined by an MSC Adams dynamic simulation that identified the most severe load condition in the duty cycle for roller skewing. A Syber™ Bearing System Analysis Program model indicated that the taxi load condition resulted in truncation of the rib-roller end contact ellipse as well as 46 KSI Hertzian rib stresses, which are above the Timken 40 KSI Hertzian rib stress guideline for landing wheel bearings.



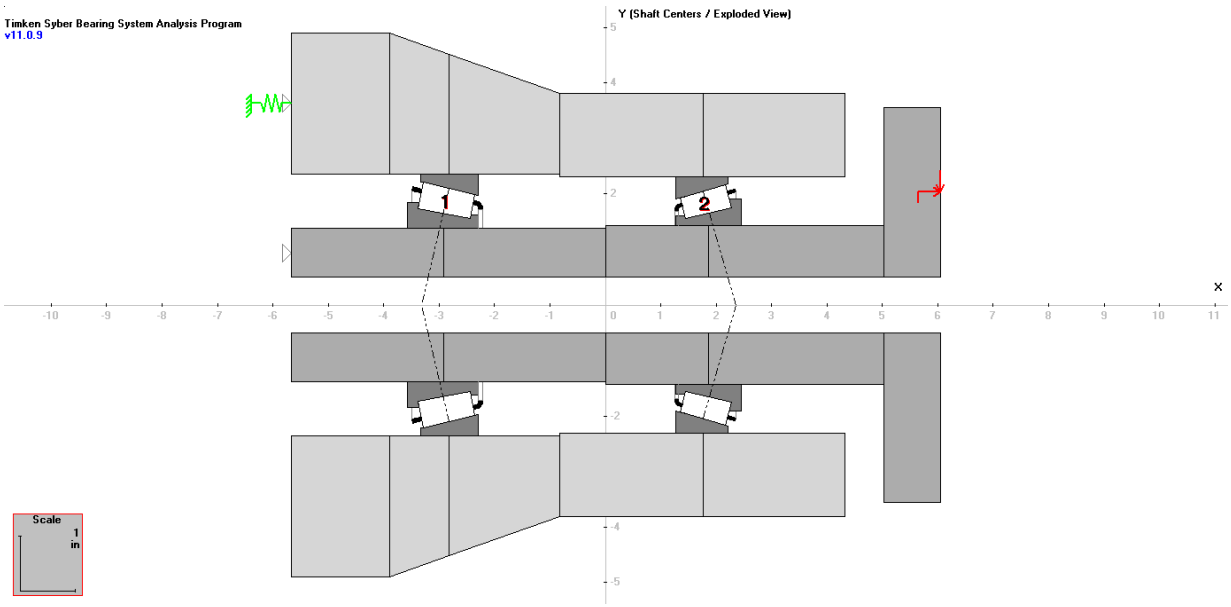
Rib-Roller End Contact Ellipse Truncation from Negative Roller Skew

The 4S test rig was used to apply radial, axial and moment loads to landing wheel bearings at various speeds and preload settings. The testing resulted in rib-roller end scoring damage that is similar to bearing damage observed in landing wheel bearing applications. The tests results below indicate that proper grease fill in the cone large rib area, grease retention and a moderate preload setting can mitigate rib-roller end damage.



Timken 4S Application Test Rig

High Hertzian rib stresses and contact ellipse truncation are associated with high risk of rib-roller end scoring, and subsequent issues of grease degradation though high temperatures, secondary debris damage, rib cracking or worse.



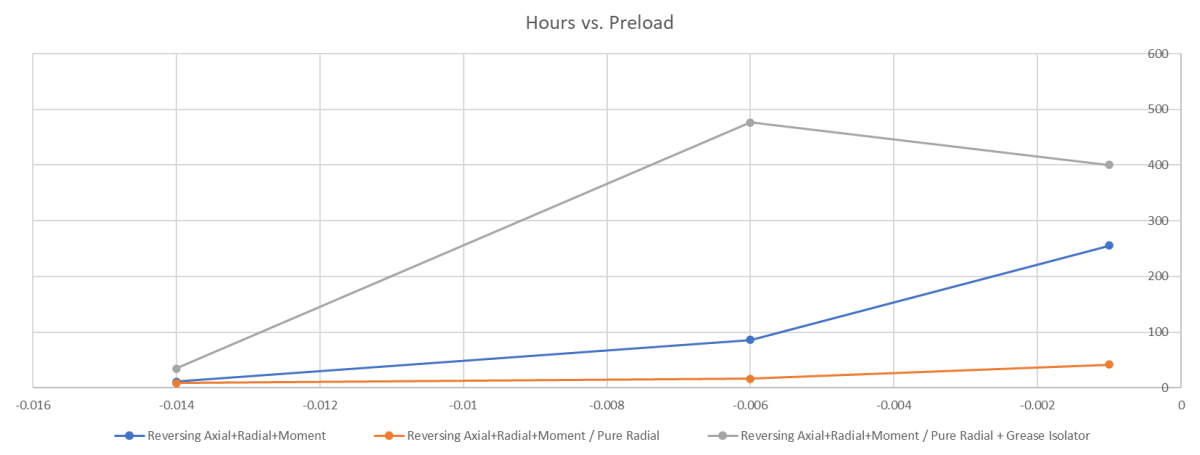
Syber™ Model of the Timken 4S Application Test Rig

The low-speed reversing axial + radial + moment load testing was initially performed without grease retention isolators. The grease stayed in the bearing well at low speeds. Subsequent tests combined low speed axial + radial + moment load test and additional tests with radial loads only that were run at higher speeds. The higher speeds resulted in the grease flinging out of the bearings at the cone large rib area. The solution was to add proper grease retention at the inboard cone large end position via an isolator and extra grease was applied to the cone large rib area. The grease retention extended the time before the test rig torque limits were exceeded by factors of three and more. High rig torque was usually the indication of rib-roller scoring damage in most of the test runs.

V. Lower Preload Settings May Extend Bearing Life

The test results indicate that lower preload settings enable the bearings to survive much longer before the scoring damage progresses. Landing wheel OEMs determine proper preload settings in conjunction with the bearing manufacturers and airframe builders, so this lower preload information should only be considered as informational, and any preload setting should be tested and confirmed by the wheel OEMs.

The relationship between higher preload and rapid scoring damage progression is not fully understood. Rib-roller end loads and stresses do not increase significantly with higher preload. A contributor may be time spent in the load zone at higher preloads since the load zone increases with preload. Another theory is that the grease is being wiped away from the cone large rib by the rollers at higher preload settings. This effect could be exacerbated if grease slumps away from the rib-roller end during idle periods, so the bearings should always be fully packed with grease per the OEM requirements in the maintenance manual. This is an area for continued Timken research.



Timken 4S Application Test Rig Hours vs. Preload Setting Results

Note that the Reversing Axial + Radial + Moment / Pure Radial life was limited due to loss of grease in the bearing.

VI. Key Points to Reduce Rib-Roller End Scoring Damage Risk

- Timken performance code 629 tapered roller bearings have rib-roller end tolerances and surface finishes that reduce scoring damage risk.
- Rib-roller end Hertzian stress below 40 KSI.
- Rib-roller end geometry can be optimized.
- Scoring damage can progresses more rapidly at higher preload settings.
- Early scoring damage is subtle in appearance and becomes more visible as the damage progresses.
- Early detection of scoring and removal of the cone assembly from service is a key to preventing catastrophic bearing damage.
- Ample grease at the rib-roller end and grease retention are crucial to reducing risk of scoring damage.
- Scoring damage is likely to be initiated at low-speed taxi load conditions.
- Scoring damage can occur during aggressive taxi load conditions (low speed, high axial, radial and moment loads).
- See the Timken Aircraft Landing Wheel Bearing Maintenance Manual for more details on tapered roller bearing handling, inspection, and maintenance.

The Timken team applies their know-how to improve the reliability and performance of machinery in diverse markets worldwide. The company designs, makes and markets bearings, gear drives, automated lubrication systems, belts, brakes, clutches, chain, couplings, linear motion products and related industrial motion rebuild and repair services.

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