Technical Article

Top Drives

Responding to the Challenge of Deeper Wells

TIMKEN

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How to Increase Top Drive Bearing Life

Responding to the Challenge of Deeper Wells

A primer on proper main thrust bearing selection, maintenance, and more

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The Timken Company is a technical leader with more than a century of oilfield experience across the globe. The complete line of Timken bearings and power transmission solutions encompasses all topside equipment and, increasingly, downhole applications including drill bits, mud motors, and liner hanger bearings.

Introduction

Rotary swivels and top drives are fundamentally simple in design but are considered one of the most remarkable devices on an oil rig. The American Petroleum Institute classifies top drives under “Drilling and Production Hoisting Equipment.” The largest of the top drives can carry a hoisting capacity of 1500 tons, have upwards of 100,000 foot-pounds of continuous torque, and withstand rotation at the rate of 600 rpm while carrying drilling fluid pressures up to 7,500 psi.

Top drives are critical in oil and gas drilling operations, which are shut down if the top drive or swivel is not operating. Financial stakes are high: Single land rigs can cost $10 million, offshore rigs more than $500 million, and new drill ships ranging from $500 million to $1.2 billion. During peak utilization times in 2013, high-end offshore rigs commanded day rates over $600,000. This means the top drives used on large deepwater offshore rigs, as well as on land rigs, require reliability and durability as uptime is crucial.

This article describes the common top drive bearing types and design layouts used in the oil and gas market. It focuses on the details of the main thrust bearing position and common application considerations in top drives, which will be highlighted.

Key Bearing Positions

The use of anti-friction roller bearings on the main shaft and throughout the transmission of top drives promotes optimal performance and longevity. Top drives are required to operate in extreme conditions, often making it tremendously hard on units used offshore or on land rigs. In all cases, bearings that tolerate demanding conditions are a necessity given the criticality of the top drive's role on the rig.

Rolling element bearings are selected for use in the following positions in top drive units:

- Main thrust bearing
- Upper radial setup bearing
- Lower radial support bearing
- Transmission (gearbox) bearings

While we will touch on factors important to all locations, this article focuses on key selection and maintenance considerations for tapered thrust bearings used in the main thrust position.

The Timken Company supports a broad bearing offering for each application position to meet different size and performance requirements.

Figure 1: Oilfield top drive, with integrated motor and transmission, hangs from the traveling block and hook in the mast. The motor turns the drill stem and bit downhole.

Top Drive and Rotary Swivel Design Differences

Top drives and rotary swivels are the two main types of drilling and load path hoisting equipment for the petroleum and natural gas industries. Swivels were invented first, which evolved into the power swivel and later into the top drive system. Top drives can generally be described as having the main shaft bearing and the transmission in a single housing.

Rotary swivel: Precision machined steel casting with streamlined contours. The kelly connects to the bottom of the main stem, below the swivel body, and drives the drill string via power from the rotary table at the rig floor.

Top drive: Comprised of one or more electric or hydraulic motors connected to the drill string by the main shaft or "quill" to apply clockwise torque during drilling. A top drive is essentially a motor that is suspended from the derrick, or mast, of the rig. Replacing the traditional kelly or rotary table, the top drive provides a more efficient drilling process capable of drilling with three combined 30-foot pipe sections (stands) instead of just one at a time. Top drives can be fully automated, offering control of weight on bit, torque, and rotation. On offshore rigs, the top drive travels up and down on vertical rails to control movement.

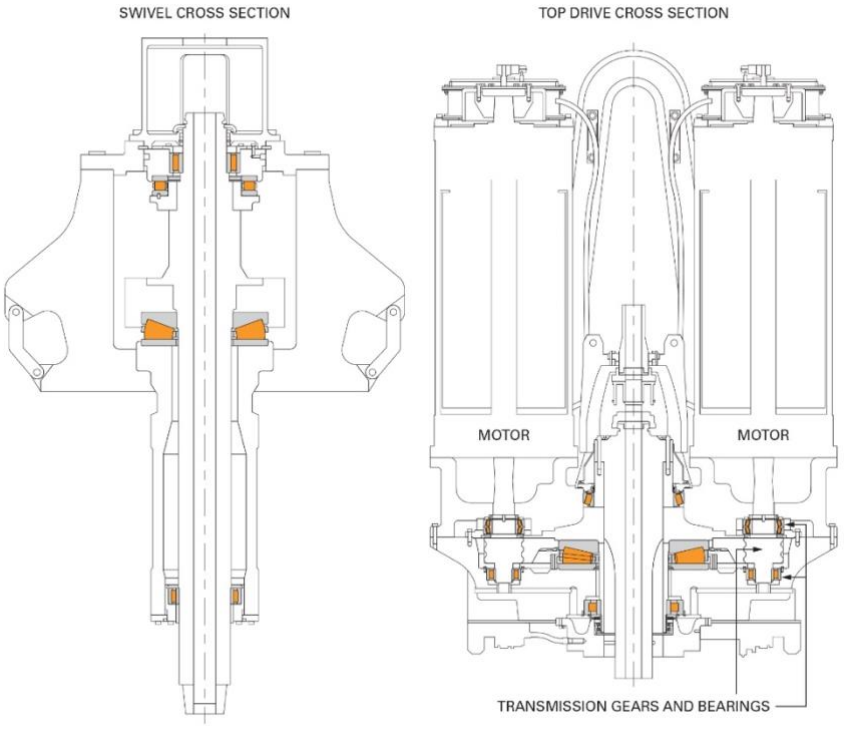

Figure 2: Swivel (left) and top drive (right). The side-by side comparison shows the complexity of the top drive, which includes transmission gears, bearings, and full lubrication system located in the main housing. The top drive uses dual AC motors, whereas the swivel is driven via rotary table at the rig floor.

Main Thrust Bearings

Main thrust bearings are high-performance, heavy-duty tapered thrust roller bearings. These bearings are (Fig. 3) tapered thrust heavy duty (TTHD) or tapered thrust heavy-duty free lateral (TTHDFL or V-flat) types.

TTHD and TTHDFL tapered thrust bearings are the most utilized type of main thrust roller bearing used on a top drive's drive stem, quill, or main shaft. Timken has a very broad offering of these products and can accommodate customer needs from a size and performance standpoint. From the smallest land rigs to the largest offshore drilling platforms, bearing bore diameters range from a few inches to upwards of 20 inches, respectively. Both the TTHD and TTHDFL bearing styles are separable in design, allowing the shaft and housing washers to be mounted separately.

TTHD-type tapered heavy-duty thrust bearings are quite prevalent in smaller bore sizes up to approximately a 10″ bore. Due to their size and commonality, these are a readily available choice for use in smaller designs.

Historically, the TTHD was the more common choice across all sizes, and catalog part numbers were often selected for use. In newer, larger top drives with very high-capacity ratings (above 10″ bearing bores), the TTHDFL bearings (one flat race) are often preferred for manufacturing and mounting advantages. *Power density*, the ability to support heavy loads in a compact dimensional boundary, is optimized via the bearing design. The default bearing cage type is also related to bearing bore and OD size, with larger bearings or high-capacity designs receiving the pin-type cage. The default cages are machined brass or pin type (steel).

The standard or "catalog bearing" with machined brass cage and roller complement is often a more cost-effective solution on smaller units. The switch to a pin-type cage increases the dynamic and static capacity of the bearing, which is beneficial in achieving the highest possible top drive or swivel rating.

Figure 3: TTHD with machined brass cage (left); TTHDFL with pin-type cage (right).

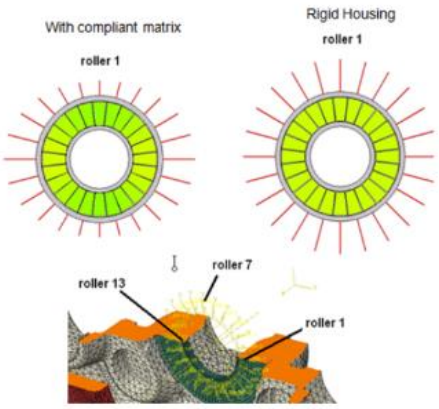

Figure 4: Syber output results with compliance matrix (top left) and rigid housing model (top right) highlight the effect on roller load distribution in the main thrust bearing with advanced modeling techniques.

Machine Upgrades and Bearing Requirements

It is important to understand how machine upgrades can impact bearing selection; for instance, when considering an upgrade to a higher API hoisting rating. This will alter the required API bearing-load rating of top drives or swivels, expressed in short tons, and the main bearing thrust rating at 100 RPM for 3,000 hours minimum life for 90% of bearings, expressed in pounds force. A properly specified bearing can provide issue-free performance, even under increased loading, while maintaining the existing bearing bore, OD, and height dimensions. In one specific enhanced bearing case, dynamic capacity increased over 40%, resulting in an API rating increase from 357 tons to 500 tons with conversion to a newly enhanced bearing.

Timken uses Syber (its proprietary analysis software) and other modeling tools to validate bearing performance and anticipate issues that may occur at bearing locations during operation. Decades of application support for enhanced top drive designs allows for a higher level of confidence in bearing life predictions based on these advanced modeling tools.

DuraSpexx® Power Rating Series: DuraSpexx® Power Rating Series bearings are excellent solutions for the TTHD and TTHDFL thrust bearings. These bearings' changes to material and the use of engineered surface enhancements allow for significant increases in capacity and overall bearing performance. Thrust bearings with surface modifications and engineered surface (ES) coatings are advantageous in debris, thin-film boundary, and mixed-lubrication conditions. These features address the root causes of the mechanisms responsible for life-limiting bearing wear.

Mixed lubrication is a regime where the lubricant film cannot fully separate the surface asperities. The engineered surface modifications of the DuraSpexx® series effectively increase the separation of contacting surfaces and reduce wear caused by the interaction of roller-raceway asperities in mixed lubrication. This can improve the lambda ratio toward a full-film lubrication regime whose film is sufficiently thick to prevent asperity contact. The ES coating creates a polishing action that continues until the contacts are fully separated by the lubricant film. Case-carburized rings and rollers are strong on the outside but retain a softer, ductile core, making these bearing components more resistant to debris damage and shock loading compared to conventional through-hardened components. Additionally, the fracture toughness of case-carburized steel is greater than through-hardened steel.

Figure 5: A 36″ OD DuraSpexx® Power Rating TTHDFL with pin-type cage and ES coated rollers (shown without flat race).

Seal Out Mud, Water, and Debris

Washpipe assemblies are an important component of high-pressure sealing technology between the main shaft and gooseneck to combat drilling mud from entering the upper bearing cavity in the main gearbox housing. The upper bearing retainer plates use a combination of lip seals and O-rings to keep the housing sealed tight from the elements. Concentricity between multiple housings and limiting angular alignment play a major role in seal and packing performance. Rotary seals, spring-loaded lip seals, and proprietary seal designs are utilized to ensure the high-pressure mud follows its intended path through the main shaft into the drill pipe. However, even with all the above design-related mitigation steps, abrasive particles can still bypass worn seals or even be generated by the wear of other components during operation.

CASE STUDY: 1250-ton top drive main thrust DuraSpexx® Power Rating Series TTHDFL

Figure 6: DuraSpexx® Power Rating Series TTHDFL flat thrust race from 1250-ton top drive after a five-year campaign.

Our case study examines a 1250-ton top drive main thrust bearing undergoing inspection after completing a full-life five-year campaign cycle (Fig. 6). The end user noted the top drive was often run very hard and there were signs of debris ingress during service.

The raceway surfaces presented in excellent condition, with the presence of only light debris denting and light lube staining. The debris denting did not progress to spalling. All traces of the raised metal edges (dent shoulders) were removed from the polishing action of the engineered surface coating on the rollers (ES302), negating the life-reducing mechanism associated with debris-dented raceways and localized stress risers in the roller path.

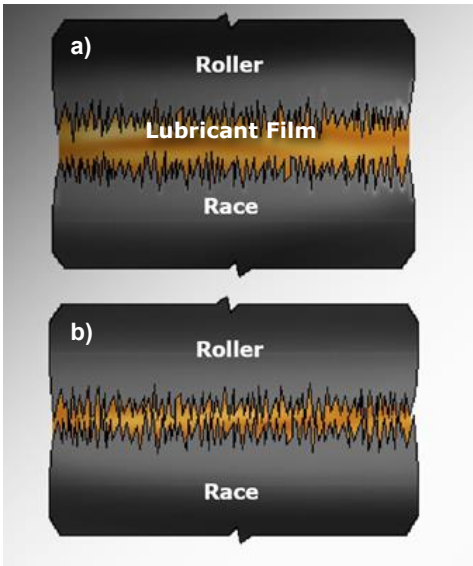

Figure 7: An effective lubricant film maintains separation between asperities on the bearing. a) Effective lubricant film with full separation of contact surfaces; b) insufficient lubricant film with asperity contact. Adhesive wear from contacting asperities reduces expected bearing life.

Lubrication Considerations

Proper lubrication in any bearing application is critical to long-term reliability and performance. The top drive main shaft rpm is low to moderate, and loading is moderate to heavy. These factors must be accounted for in the initial bearing lubrication selection.

Bearing positions in top drives are mostly oil lubricated, particularly in the main shaft and transmission bearing positions. There are special design cases with grease lubricated main shaft bearings, which are installed above electric motors. This design differs from the traditional approach of a circulating oil and filtration system to lubricate all bearing positions in the transmission.

End users are tasked to select the best lubricant for their specific operating conditions based on equipment manufacturers' guidelines, including suggestions for different seasonal or ambient temperature ranges. There are many considerations when choosing a lubricant, and in certain instances, laboratory testing can help determine the ideal formulation.

One should consult with the equipment manufacturer for their recommended oil change interval. Initial oil changes are conducted after run-in periods. One example is after the first four weeks or 500 hours of operation, whichever comes first. Other standard inspection procedures may reference a specific number of operating hours or a more general description of days in service or qualifying events (e.g., daily, every three months, or once per year or earlier based on oil analysis). Additionally, proper lubrication flow should be checked after every oil change to ensure bearing positions aren't starved for oil.

A suitable oil lubrication maintenance schedule allows gearbox oil viscosity to be adjusted based on expected ambient conditions or scheduled time between changes, after oil analysis is performed. Finally, the oil level in the transmission is typically checked daily via sight gauges with the top drive "OFF."

Appropriate oil filtration helps maintain performance while extending the life of top drive geartrain components. Some of its benefits include:

- Reduced damage rate of bearings, gears, and rotating components
- Equipment and lubricant life extended as wear particles are removed
- Cleaner oil, which means cooler oil and lower operating temperatures
- Improved machine efficiency while reducing maintenance time and costs

Tapered thrust bearings

Tapered roller bearings

Cylindrical roller bearings (single row)

Spherical roller bearings (two-row)

Extend Bearing Life in Top Drives

A properly selected top drive bearing should provide a minimum of five years of reliable field service under various drilling conditions to reach the desired time between major rig overhauls. Drilling conditions range from mild to extreme and there's always a chance for a surprise event along the way. The replacement of main shaft or transmission bearings is completed in a certified repair facility, as a tear-down of this scope would be next to impossible onsite. The costs associated with repair are consequently causing many top drive manufacturers and drilling contractors to implement solutions to extend their overhaul intervals, along with increasing roller bearing life and performance.

Manufacturers like The Timken Company can model top drive design changes (or upgrades) to ensure adequate service life and can suggest bearing upgrades for improved reliability. Adding new data sets to existing application models allows bearing geometry to be adjusted to solve emerging challenges quickly and efficiently.

There are many bearings designed specifically for top drives that will provide a suitable off-the-shelf solution; however, it can be beneficial to look at bearing enhancements, particularly where demanding drilling conditions are possible.

Ask your expert about bearing modifications as well as special enhancements that create advantages in heavily loaded or thin-film conditions. Enhancements can include premium materials, enhanced finishes, or engineered surface coatings to provide more wear resistance and longer life compared to standard bearings.

A tapered thrust bearing optimizes design life per unit volume (power density), has low torque to rotate and high stiffness because of its large contact angle, and can be designed to provide a favorable roller/raceway stress distribution. The drilling industry has significant experience with TTHD and TTHDFL designs currently being used in top drive main bearing positions.

First employed in a top drive in 2001, the DuraSpexx® Power Rating Series, with enhanced material, proprietary profiles, surface engineering technologies, and increased load ratings recognized by the American Petroleum Institute (API), are used in some of the harshest drilling conditions the world over.

Tips for Bearing Service or Selection

In addition to the many considerations above, it is also important to note the following when servicing top drives or selecting bearings:

- Use an approved method to heat bearings prior to installation on a shaft. Other methods cannot achieve the same consistent, safe results.
- Keep a detailed log of bearing maintenance procedures, particularly relubrication intervals. If a problem with your bearings does occur, this can make it easier to diagnose the issue.
- When relocating top drives, be aware of the critical difference geographies can have on lubricant performance. A top drive using a cold weather oil formulation can encounter problems if moved to a warmer region.
- Remember that one size does not fit all — similarly sized top drives can have vastly different operating demands, meaning bearings must be selected for the specific environment and duty cycle.

Depend on Timken Quality

Top drives demand roller bearings designed and built for years of trouble-free service. Where reliability is an issue or where API hoisting ratings are being increased, an enhanced bearing is often the solution. When properly specified and maintained, top drive roller bearings can operate trouble-free for many years.

The Timken Company design and manufacturing processes are engineered to provide the highest levels of quality — bearing after bearing. Our track record for reliability has made Timken a recognized name in oil and gas drilling and has been involved with the development of API equipment operating standards for more than 90 years. We're also an active participant in IADC Maintenance Committee meetings and in developing standards for both the American Bearings Manufacturers Association (ABMA) and the International Organization for Standardization (ISO).

Our vast application knowledge is available to help you increase uptime and reduce maintenance costs wherever top drives operate. Start a conversation with a Timken bearing expert today.