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Technical Article

How to Increase Mud Pump Bearing Life

Responding to the Challenge for More Power

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A primer on proper selection, maintenance and more

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Timken 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

Mud pumps, used for oil and gas drilling operations, get their name from the specially prepared fluid (mud) that is pumped through the drill pipe to evacuate cuttings from the hole, as well as to cool and lubricate the drill bit. These are generally low-speed, high-displacement reciprocating pumps and can be either single- or double-acting, with the majority in use today being single-acting. Mud pumps can also feature from one to five cylinders, with a triplex arrangement being the most common. Normally, the pumps are skid mounted for transportation purposes, with the majority being horizontal in design and incorporating a fluid and power end, which are separate for maintenance purposes. This article explores the power end where roller bearings are located.

Upgrades to mud pumps now allow for working pressures up to 7,500 psi continuous operation where flow rates can approach 1,000 gallons per minute, with the largest units being rated at upwards of 3,000 horsepower. In many ways, mud pumps are the heart of the drilling operation considering the steep cost of downtime for a land rig or deepwater platform that has experienced an unexpected shutdown event. For this reason, multiple mud pumps are often installed to achieve the desired drilling pressure and flow rate, typically with a reserve unit(s) at the ready. With the industry pushing to increase horsepower and pressure, design changes or upgrades can challenge bearing performance.

Mud pumps are used in oil and gas drilling operations.

Four Key Bearing Positions

The use of anti-friction roller bearings throughout the power ends of mud pumps can help promote optimal performance and longevity. Mud pumps are often required to start under full load, making it extremely hard on units designed around sleeve-type bearings (bushings) that are frequently used in both positions of the connecting rods of frac pumps, for example. Mud pump bearings are hard to service on site. Therefore, the bearings need to tolerate demanding conditions to minimize the need for maintenance and expensive downtime.

This article focuses on key selection and maintenance considerations for common roller bearing designs used in the four primary mud pump application positions:

- Main bearings (crankshaft support)
- Pinion bearings (input)
- Eccentric bearings (connecting rod, large end)
- Crosshead or wrist pin bearings (connecting rod, small end)

Timken supports a broad bearing offering for each application position to meet different size and performance requirements. Pinion and crankshaft bearings are radial bearings and the type used will vary depending on the pump model. These bearings (Fig. 1) can be single- or double-row tapered roller, spherical roller, or cylindrical roller types.

Figure 1: This group of bearings includes a Timken single row tapered bearing cone and cup (front center), Timken® high-performance spherical roller bearings (back left), and cylindrical roller bearings with machined one-piece brass cage (back right).

Mud Pump Design Differences

As previously noted, most mud pumps are single-acting designs; however, very early pumping applications used double-acting designs.

In a single-acting design the load is consistent in one direction. As a result, there is one distinct and relatively constant load zone in the outer race of the connecting rod bearings. The connecting rod max radial load is generated during the pump/discharge stroke, with negligible connecting rod loads present during the suction stroke.

In a double-acting design the load is changing direction. Therefore, there are two distinct and relatively constant load zones in the outer race of the connecting rod bearings, as significant connecting rod load acts in two directions.

Bearing life calculations and fitting practice for single- and double-acting pumps are the same with one exception being eccentric bearings. In a single-acting design, since the eccentric bearing is only heavily loaded on one end of the stroke, the actual speed of the crankshaft is used in the life calculations. In a double-acting design, twice the crankshaft speed is used in the bearing life calculation to account for the two distinct load zones.

Mud pumps are single-acting or double-acting designs. These design differences are a factor in bearing performance.

Main Bearings (Crankshaft Support)

Crankshaft main bearings (Fig. 2) were historically sized using a factor for the load equal to 80–85 percent of the rod loading, using a life target of 20,000–40,000 hours L10.

Figure 2: Crankshaft with connecting rods, eccentric, and crosshead bearings before main bearing installation.

Tapered roller bearings tend to be a good choice for the main position and are widely used on a variety of oilfield rotating, drilling and hoisting equipment. These bearings are simple to mount and perform well in severe conditions. A common bearing selection is a two-row double outer race (TDO) arrangement (with cone spacer). TDO bearing assemblies (Fig. 3) are normally selected with a matched spacer that requires no grinding or manual adjustment by customer. This arrangement provides a wide effective bearing spread, making it ideal for applications in which overturning moments are a significant load component.

Spherical roller bearings (Fig. 4) have also been used for the main position with either tapered or cylindrical bores. These bearings use a brass cage that offers strength and durability benefits over standard steel cages.

Tapered bore, spherical roller bearings are mounted on either solid or hollow tapered journals. Mounting directly on tapered journals requires accurate grinding and gaging of the journal to help achieve optimal bearing performance. Deficient journal diameter, section thickness, form and surface roughness can produce insufficient support of the bearing inner ring, uneven bearing load distribution, bearing inner ring slipping relative to the shaft, and fretting corrosion damage, or excessive bearing inner ring tensile hoop stress. All are undesirable and can lead to premature bearing damage. Therefore, original manufacture, maintenance, and accurate measurement of shaft tapered journals are important. This also applies for cylindrical shafts and housing seats.

Figure 3: TDO bearings having a double cup and two single cones (with or without a spacer) can be used in fixed positions or allowed to float.

Figure 4: An option for the main bearing position is a spherical roller bearing with brass cage for extra strength and durability.

Radial expansion of the tapered bore inner ring occurs when mounting. Deflection between a solid and hollow journal differs due to the journal wall section thickness and flexibility. For the hollow journal mounting, this results in differential radial expansion across the inner ring, distortion of the inner ring and journal as they cycle through the load zone, and axial gradients in contact pressure distribution. The thinner inboard side of the bearing inner ring expands more on the thicker inboard section of the journal. On a rigid shaft of proper manufacture and taper, there is little differential pressure across the bearing.

Effects on Spherical Roller Bearing Radial Internal Clearance

Bearings mounted on tapered journals must be installed to reduce the initial radial internal clearance (RIC) by the specified amount for the selected part number. A hollow journal can require the bearing to be axially located further up the taper than a solid journal, therefore proper reduction in RIC is most critical and the method used to verify mounted clearance. The tabulated axial push values should not be used with a hollow journal. Failure to accomplish this will result in inadequate interference fit between the bearing inner ring and journal. Relative motion may occur, which is not desirable and may result in bearing and journal damage. The effects of inner ring movement can be seen in the bore of bearings removed from service, in the form of fretting and/or galling. Likewise, RIC reduction greater than specified should be avoided due to development of excessive inner ring stresses. ANY deviation from tabulated recommendations should be checked against OEM manuals, and it can be reviewed by Timken engineers.

Both tapered roller and spherical roller main bearings accept radial, and any locating axial load from the crankshaft. It is common for crankshaft main configurations to use a fixed/float or semi-float bearing arrangement with constraining housing shoulders depending on the OEM frame design.

Machine Upgrades Change Bearing Requirements

It is important to understand how machine upgrades can impact bearing reactions. For example, when considering a single-motor mud pump to be converted to two motors to meet new power demands, the pinion bearing reaction will be altered and impact life calculations. Changing the design configuration of a pump can result in unexpected bearing performance issues if the design is not properly evaluated for increased reaction forces. Timken uses proprietary SYBER analysis software and other modeling tools to anticipate issues such as unloaded rows or roller skidding that may occur inside bearings due to machine modifications.

Pinion Bearings (Input)

Timken can help provide a higher level of confidence in bearing life predictions based on advanced modeling tools and decades of application support for mud pumps. Pinion support bearings (Fig. 5) were historically sized only from the gear loads. For a more accurate analysis and bearing life prediction, the resulting pulley loading from the drive motors also needs to be considered. Pinion bearings can be tapered roller, but spherical roller or cylindrical roller selections are more common.

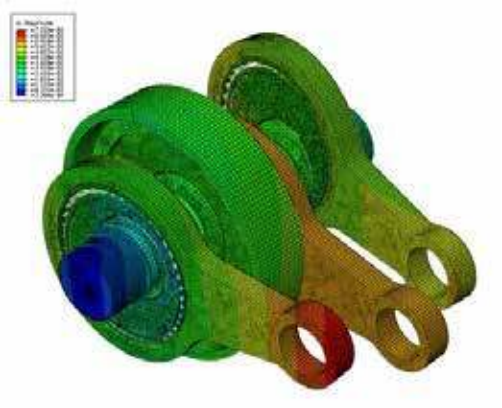


Figure 5: Results of FEA (Finite Element Analysis) showing complete crankshaft assembly with crosshead/ wrist pin bearings omitted.

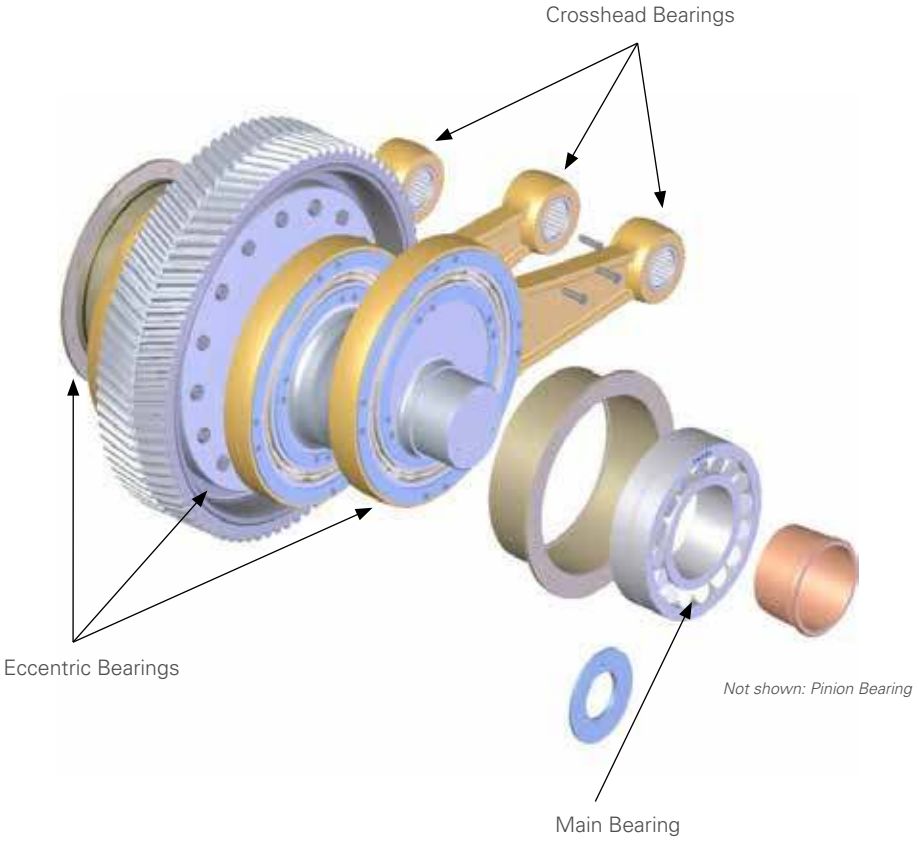
The pinion bearing positions have the highest bearing operating speed in the pump, but are furthest removed from the oil sump. Lubrication is important in all positions, but must be delivered to both pinion bearing positions for proper bearing operation and to avoid starvation conditions. An oil pump allows for lubrication delivery to each position, as oil splash alone, is not the most effective means of keeping the bearings properly lubricated. In pumps with elevated operating temperatures, typically above 160 degrees Fahrenheit, oil cooling systems are often used to maintain a controlled operating temperature. Proper lubrication and cooling the oil helps prolong the life of the both the bearing and the oil.

Figure 6: View of installed crankshaft assembly with rear cover removed.

Eccentric Bearings (Connecting Rod Large End)

Eccentric bearings (Fig. 6) were historically selected to achieve catalog life target of 20,000–40,000 hours, or the default reliability set by the OEM. These tend to be robust bearings with designs dating back to the 1960s and 70s that in some cases may not be optimized for today's more extreme operating conditions. Eccentric bearings support the fluid end reactions forces, which are calculated based on the piston size and the maximum pump pressure rating. This usually depends on the pump manufacturer and the type of service the pump is expected to see.

Four-flanged locating-type cylindrical roller bearings are used in these positions and are the largest bearings in mud pumps. Selection is dictated by the combined requirements of high bearing dynamic load rating, and the crankshaft design to achieve the piston displacement. Since the bearing must also locate the connecting rod relative to the crankshaft, it must offer a moderate amount of thrust capability in both axial directions.



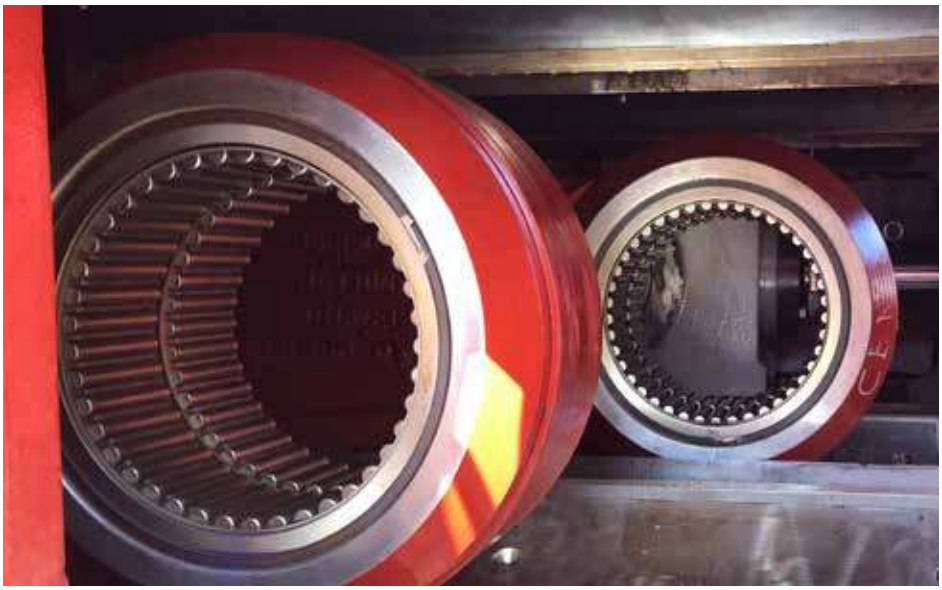
Bearing locations identified in expanded view of mud pump crankshaft with connecting rods.

Crosshead/Wrist Pin Bearings (Connecting Rod Small End)

Crosshead (or wrist pin) bearings were also historically sized using a catalog life target of 20,000–40,000 hours L10. This position is located at the opposite end of the connecting rod at the work or piston end. Most commonly employed at the piston end is a two-row HJ heavy duty cylindrical roller bearing. This design allows for extremely high load capacity relative to the minimum space present for the bearing. These bearings can be designed for use without an inner race, but the shaft must be heat treated to a minimum of 58HRC and ground to achieve proper diameter, form and surface finishes. Small mud pumps may operate with these bearings mounted directly on a hardened and ground pin. Large mud pump crosshead bearings usually include an inner race.

Crosshead/wrist pin bearings are mounted tight on the shaft and in the housing, with the goal of achieving a very low radial internal clearance in the mounted position. Loading conditions are very similar to those for eccentric bearings; consequently, the same tight-fitting practice is used. The difference between the two positions is that crosshead/wrist pin bearings experience oscillating motion due to the connecting rod stroke. Because of the slow relative speed, lubrication film thickness is minimal and there can be increased metal-to-metal contact that introduces wear, among other potential damage modes.

Bearings subject to oscillations must be sized, and life calculated differently, then bearings that strictly rotate.



Pictured are Timken right and center crosshead wrist pin bearings. Bearings were used in mud pumps.

Lubrication Considerations

Proper lubrication in any bearing application is critical to long-term reliability. Generally, mud pump speeds are moderate to low, with loading being moderate to heavy. These factors must be accounted for in the initial bearing lubrication selection.

All bearing positions in mud pumps are oil lubricated. For the two larger bearings, particularly in the main and eccentric positions, oil viscosity is a key consideration, due to their moderate operating speed. Suggested viscosity for hotter pump operating temperatures or warm climates is ISO VG 460, constituting a thicker oil typical of high-load synthetic lubricants to help maintain lubricating film strength between bearing contact surfaces. Because all positions other than the pinion bearings tend to operate in thin film conditions, oils with a high viscosity index help to protect components over a wider temperature range.

Higher viscosity oils, like ISO VG 460 are commonly used, sometimes with the addition of a molybdenum disulfide (MoS_2) additive package, to promote reduced friction and wear inside the bearing by increasing the resiliency of the lubricating film. In all cases, it is important that the additive package is compatible with the mineral or synthetic lubricant selected.

End users tend to select the best lubricant for their specific application 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.

Spherical Roller Bearings

Tapered Roller Bearings

Cylindrical Roller Bearings

HJ Heavy Duty Cylindrical Roller Bearings (two-row)

Extend Bearing Life in Mud Pumps

A properly selected mud pump bearing can help achieve a minimum of five years of reliable field service under normal drilling conditions to reach the desired time between major rig overhauls. The replacement of connecting rod eccentric bearings or the entire crankshaft is no small matter and can take a crew of four or five individuals an entire week to complete. Thus, many pump manufacturers and drilling contractors are starting to look at options to extend their pump overhaul intervals, along with increasing roller bearing life and performance.

Timken can model mud pump 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 can allow bearing geometry to be adjusted to solve emerging challenges quickly and efficiently. There are many bearings designed specifically for mud pumps that will provide a suitable off-the-shelf solution; however, it can be beneficial to consider bearing enhancements, particularly when mud pump upgrades are planned.

Ask your bearing supplier about bearing modifications as well as special enhancements that create advantages in heavily loaded or thin-film conditions. Enhancements can include engineered coatings on rollers and on raceways that provide more wear resistance compared to standard surface finishes. Case carburization is also an option for bearing applications where loads are severe. 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.

Drilling operations rely on durable roller bearings. Mud pumps especially demand stronger solutions.

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Tips for Bearing Service or Selection

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

- Only use an induction heater to heat bearings prior to installation on a shaft. Other methods cannot achieve the same consistent 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 mud pumps, be aware of the critical difference geographies can have on lubricant performance. A pump using a cold weather oil formulation, can suddenly encounter problems if moved to a warmer region.
- Remember that one size does not fit all – identical pumps can have vastly different operating demands, meaning bearings must be selected for the specific environment and duty cycle.

Depend On Timken Quality

Mud pumps demand roller bearings built for years of trouble-free service. Where reliability is an issue or where pumps are being upgraded, a stronger bearing solution can often benefit operations. When properly specified and maintained, mud pump roller bearings can operate trouble free for many years.

Timken 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. We're also an active participant in developing standards with the American Petroleum Institute (API) and 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 mud pumps operate. Start a conversation with a bearing expert today.

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 high-performance mechanical components, including bearings, gears, belts, chain and related mechanical power transmission products and services.

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