HEAVY MOVABLE STRUCTURES, INC.

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INSTALLATION AND HANDLING OF LARGE BORE ROLLING ELEMENT BEARINGS IN MOVEABLE BRIDGES

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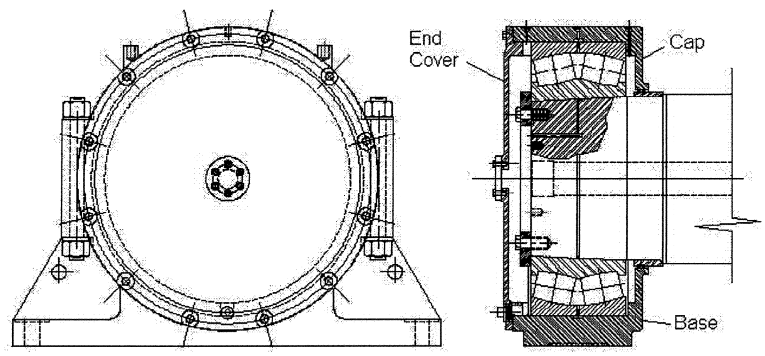
MACHINERY/MECHANISMS

Introduction

This paper discusses the proper handling and installation practices of large rolling element bearings and pillow blocks commonly used in vertical lift and bascule bridges. Most commonly the spherical roller bearing mounted on a tapered trunnion with a three-piece pillow block are used to support vertical lift sheaves and bascule pivot shafts. A three-piece pillow block consists of a base, cap and end cover. Although pillow block assemblies can be of various arrangements, most bearing installation practices are only slightly different. Proper care in handling and installation completes multiple years of engineering and design that go into new moveable bridges or extensive rehabilitations. Following a predetermined installation procedure gives the bearing the best opportunity to achieve its life and performance expectations.



A typical three-piece pillow block with a mounted tapered bore spherical roller bearing.

Preplanning

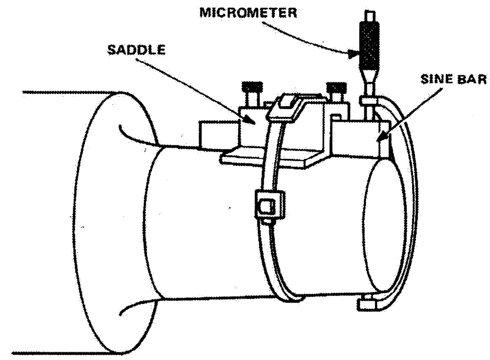
Importance of Inspection

The bearing installation procedure actually begins months before all components arrive on the jobsite. Trunnion and housing inspections are one of the most important procedures in the bearing installation. With such high loads, the importance of correct size and form of the trunnion and housing are magnified. Heavily loaded bearings require additional support and consistent mounting surfaces to avoid localized load zones. Inadequate support for the bearing promotes high roller contact stress that can reduce the life of the bearing. The bearing manufacturer will be able to provide bearing customer prints detailing the bearing sizes, tolerances and the manufactured RIC. Trunnion and housing diameters and tolerances should also be provided prior to manufacture and should be applied to the detailed plan prints.

Journal Inspection

To avoid damage to the trunnion and bearing bore, most large bore spherical roller bearings use an interference fit developed as a result of pushing the bearing up a 1:12 or 1:30 taper. The use of a tight fit prevents relative movement between the shaft and inner ring minimizing the chance of fretting or galling damage. Since the bearing inner ring is relatively flexible compared to the trunnion, it will take the roundness characteristics of the trunnion after being mounted. Therefore it is of extreme importance to monitor the size and form of the trunnion using a sine bar. The dimensions over the sign bar should be generated by the bearing manufacturer and given to the mechanical contractor during the detail design phase. Often the trunnion is sized in a way that gives very accurate control over the final axial location of the bearing, pushup plate and shaft seals.

The recommended sine bar should be placed on the tapered trunnion with its thick end aligned with the small diameter end of the tapered trunnion. The end of the bar should be aligned with the end of the taper and secured with the saddle provided in the sine bar kit. The diameters should be measured over each end of the bar and checked to the print specification. The sine bar and saddle should be rotated 45 degrees and the procedure should be repeated. These four measurements will be used to qualify diameter, roundness and taper of the trunnion seat.



The sine bar permits gauging of the tapered shaft seat.

The bearing manufacturer will be able to provide a detailed procedure for taper inspection and have the sine bar kit in their product offering. A bearing representative should complete a final check for compliance to the detailed design to make sure the taper is suitable for the bearing. The final check for size, roundness, taper, and surface finish should be completed at the mechanical contractor's location so that modifications can be completed if needed and still maintain project schedule.

Housing Inspection

Similar to the trunnion, the size and form of the housing is critical. Maintaining the proper housing size and form will ensure that the bearing has suitable support surfaces. Again, the bearing rings will take on the shape of the mounting surfaces under extreme or heavy loading conditions. It is important to have a block design that provides substantial support in the load zone and is as round as possible. The bearing manufacturer, noting whether the block will house a fixed or float bearing, should advise the housing bore size, roundness, taper allowances and surface finish. Excessive housing clearance has the potential to severely reduce the bearing's ability to generate wide load zone resulting in the generation of excessive roller contact stress. A clearance deficiency will inhibit the bearing's ability to float inside the block. Excessive taper could create differential loading between rows resulting in an increased contact stress pattern and possible ring fracture. Typically the housings and trunnions are manufactured at the same location so the bearing manufacturer representative will be able to inspect the housings during the same visit with the use of a bore micrometer.

The housing diameter should be measured in no less than three places, 0, 45 and 90 degrees. These dimensions will be used to qualify the housing size and give an indication of roundness. The same measurements should be taken at three places along the width of the bearing seat. These variations will give an indication of taper in the housing. All of the measurements should be recorded for the installation file.

Plan the Work

The contractor and bearing manufacturer should both have copies of the plans and component lists to review well in advance of the actual installation. A meeting should be organized several months prior to the installation date to discuss the procedure, generate a list of material and installation tools needed, and plan for contingencies. Topics to discuss during this meeting should include:

- Installation procedures / assembly instructions
- Required installation and cleaning equipment
- Crane availability
- On-site personnel availability
- Packaging, preserving and repackaging
- Push-up and removal procedures
- Contingency plans and backup equipment
- Timing
- Documentation and photography requirements
- Lubrication requirements

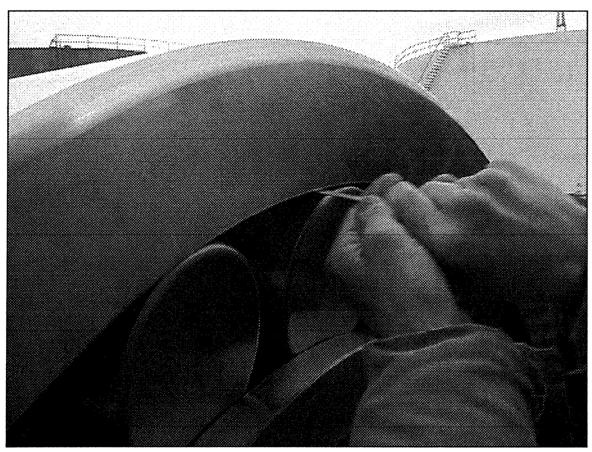
A well-organized installation can uncover potential problems that might occur on site. Hopefully any problems can be planned for and avoided to help maintain the project schedule.

On-site Bearing Preparation

Radial Internal Clearance

Radial internal clearance (RIC) is the total amount radial play in a bearing, which can be easily measured using a set of feeler gages. The difference in the amount of RIC as measured prior to pushup and the amount measured after installation is the best indicator of the proper interference fit between the inner ring and trunnion. The difference in these numbers is a direct measurement of inner ring radial expansion and an indicator of fit pressure. Standard procedures for measuring RIC are normally provided with the bearing.

The bearing manufacturer representative will measure the RIC on site prior to mounting. The bearing will be set upright and the RIC will be measured at the 12 o'clock position over each row of rollers. The average of these two reading will be considered the bearing's measured RIC. Since the bearings are so heavy and unsupported at this point, an amount of ring sag will be realized. This sag value will be different for each bearing size and series based on its rigidity. The bearing manufacturer will be able to provide the sag values for each particular bridge bearing.



The bearing should be blocked while the RIC is measured at 12 o'clock.

Cleaning

After the bearing's RIC has been determined, there is an opportunity to clean all surfaces to rid the bearing of any foreign materials that may have found its way into the internal cavity. The bearings should be packaged and shipped to the jobsite from the manufacturer clean, preserved and ready for mounting however, sticky corrosion inhibitor invites dust and debris to adhere to it. It makes sense to take the additional precaution to clean and inspect for foreign debris that may have found its way into the bearing from the jobsite. Something as small as a single hardened metal flake in the bearing's load zone could damage the raceway and eventually develop into a spall after some time in service.

A fast and convenient way of cleaning the preservative is to use plenty of mineral spirits in spray cans and a collection of clean white rags. The spray cans can be used with long spray nozzles to reach into the bearing and flush all areas. Rollers and raceways can further be wiped with the white rags to determine their cleanliness. An outer ring lube hole should be placed at the 6 o'clock position to allow a path for the mineral spirits to exit the raceway. After the bearing has been cleaned it can be preserved for storage or installed right away. It is not recommended to leave the bearing unpreserved for an extended period of time. Based on the installation schedule, the cleaning process can even take place after pushup.


The bearing housing is being cleaned and prepped for bearing installation.

Along with the bearing, the trunnion and housing should also be clean. Most large taper trunnions have a hydraulic removal groove and inlet holes that can often catch debris. The connecting holes should be brushed and flushed to remove any trapped metal flakes. This removal feature can be used for installation by helping to expand the inner ring and as a method to lubricate the trunnion/inner ring interface. As much as a single metal filing on the trunnion could keep the inner ring from sealing the removal groove so it is important to make it completely clean. Preserve the trunnion with a light coat of machine oil after cleaning is complete. Although not as critical as the trunnion, the housing seat should be inspected for burrs and cleaned. Vent holes and lube port should be clear and free from contamination.

Installation

Lifting

With the bearing blocked and sitting upright, it now needs to be lifted onto the trunnion. Depending on the cross-section of the outer ring, it can either be choked around the outer ring circumference or a lifting strap can be fed through the bearing cavity slinging the bearing by its outer ring. It is important to discuss the lifting methods prior to installation to select the method that has minimal distortion of the rings. After the bearing is mated to the trunnion it needs to be tied to the sheave to prevent it from sliding off the trunnion. The bearing should be anchored by its inner ring or symmetrically from its outer ring. The spherical roller bearing will accept misalignment so it is important that the outer ring not be exposed to a moment load. The bearing can be untied after the pushup plate is secured to the end of the trunnion.

Pushup

There are many different ways to push a tapered bore bearing up a tapered trunnion. The most common is to use a pushup plate and an array of high strength bolts in the end of the trunnion. Pushing the bearing up the taper creates the interference fit holding the inner ring in position. The initial RIC was measured and recorded previously. Each manufacturer recommends a different amount of RIC reduction to develop a predetermined fit pressure. To avoid overstressing the inner ring, RIC reduction recommendations should not to be interchanged between manufacturers. The bearing should be hung on the trunnion and the pushup plate attached. Turning each bolt to a predetermined torque setting established by the manufacturer should snug the plate. This will be considered the "zero" point. A dial indicator can be used to measure the axial displacement from this point to its final location. This is a good reference to watch during the installation. The bearing should be rotated until the rollers are seated and the outer ring is aligned with the inner. No portion of the roller should extend beyond the outer ring raceway during pushup. A final RIC measurement can be taken for each row.

Mounting begins as the pushup bolts are torqued until the RIC reduction is realized. The bolts should be lubricated to reduce the friction while turning. It is helpful to label the bolts in the pattern that they will be torqued. Torquing to the typical star pattern is sufficient being sure not to turn the bolts more that half a turn each time. After each round the RIC and axial movement should be checked. This method is time consuming and often tiring if the proper automatic tools are not available on site. Knock wrenches with sledgehammers should be available as a backup. The hydraulic removal groove can be pressurized at this point to help expand the inner ring and further lubricate the sliding surfaces. Pressurizing the groove to approximately 1,500 psi on most large bore bearings will significantly ease the pushup force required while indicating satisfactory inner ring/trunnion fit. A hydraulic fluid leak indicates poor conformity. If this condition exists it is recommended that the bearing be removed from the trunnion. Both components should be checked for debris. Turn the inner ring 90 degrees and reinstall.

When the recommended clearance has been removed the axial displacement can be checked for reference. The final RIC and axial displacement should be recorded. The bolts should then be torqued to the same setting and wired in their final position to ensure they do not loosen over the years. Finally, the bearings should be covered and prepared to be mated with their housings.

Final Assembly

Shaft and Housing Interface

Because of the inconvenience and cost of replacing rubber lip contact shaft seals, a maintenance fee non-contacting seal is desirable. The piston seal ring method offers adequate sealing action for most moveable bridge applications. Multiple piston seal rings provide a labyrinth creating a barrier between the grease and atmospheric elements.

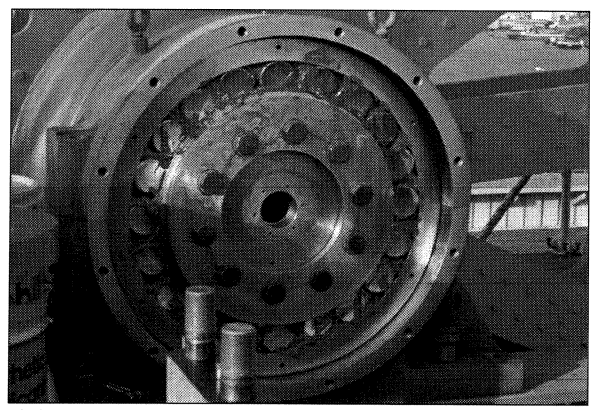
The design typically uses a minimum of two piston seal rings of bronze material manufactured larger than the housing shaft hole. The two piston rings are fitted into grooves cut in a seal carrier which is mounted on the trunnion. The seal rings are relatively fragile and are sensitive to the installation. The cap and base of the pillow block compress the split seal rings creating an interference fit with the mating sections of the cap and base. The seal carrier will rotate with the trunnion as the seals stay stationary with the housing. This creates a typical labyrinth type arrangement. Care should be taken when installing these rings since they will not be able to be replaced over a mounted bearing should they become damaged. Finally the float bearing should be positioned half way along its pillow block seat to ensure that it has enough room to move axially in each direction. Failure to do this made preload the bearing under extreme temperature changes and lead to an overload condition.

The bearing is being lifted on to the trunnion. Piston seals can be seen on the right.

Lubrication Practices

Most pillow block applications using slow rotating rolling element bearings with intermittent operation use extreme pressure grease as the lubricant. Depending on the environment, different additive packages can be recommended to meet specific needs. Most lubricant suppliers can recommend available additive packages to suit most all operating and corrosion prevention needs. The purposes of bearing lubrication are:

- Generate a film thickness to prevent metal to metal contact
- Create a barrier between the bearing and contamination from the environment
- Preserve the bearing and prevent corrosion
- Resist moisture that finds its way into the bearing cavity
- Fill the void volume inside the bearing and housing



Grease is pumped into the bearing cavity completely covering the bearing rollers and raceways prior to startup.

Although there are many grease manufactures that offer premium extreme pressure greases for bearing applications, the bearing manufacturer would recommend premium greases with the following characteristics:

- NLGI Grade 1 or 2
- Base oil viscosity of 8000 SUS at operating temperature
- Calcium or lithium base soap
- Water resistance
- Anti wear agents
- Oxidation resistance
- Good rust protection

- EP additives
- Tacky/Adhesive texture
- Ability to slump in the raceway
- Suitable for automatic lube systems
- Provides these properties over the ambient temperature range

With such high loads and slow speeds it is difficult to generate a hydrodynamic film. Rollers do not rotate fast enough to "hydroplane" so the most effective lubrication is one with a high base oil viscosity and the characteristics listed above.

A sealant should be applied to the cap and base split line as well as the end cover connection to completely seal the block from leaking lubricant. In most cases it is desirable to fill the bearing and housing's void volume completely with grease while slowly rotating the bearing to remove all air pockets. Grease should be pumped into the bearing cavity completely filling the void volume of both rows of rollers. The end cover should be attached to the cap and base before filling the remainder of the housing. A completely filled block reduces the chance of forming condensation internally during significant temperature fluctuations and humid weather. In some cases a roadway or a machinery house does not protect the blocks. They can be exposed to water spray, rain, wind and snow. In these extreme cases the lubrication is susceptible to water ingress and should be able to deal with it accordingly. As stated earlier, the piston seal ring with grease lubrication is adequate. It is not uncommon for the seals to purge grease under initial startup and during run in periods. Thermal expansion and hydraulic pressure will have a tendency to expel an amount of grease that can easily be collected. Purging will subside when pressures have been equalized. This purging should not be confused with grease leakage. Grease leakage is the result of improper choice of seal design or poor installation practices.

The advantage of using a grease lube is that samples can easily be taken to determine its effectiveness. Water content and contamination level can easily be identified to determine the adequacy and effectiveness of the sealing arrangement. Although each bridge environment and operating conditions are different, the practice of taking a lube sample is the best way of determining how the bearings are operating. Even when the blocks are covered and not exposed to the elements, a sample schedule for lube inspection can be established by the bearing manufacturer and maintenance personnel. To gain knowledge to the frequency required for lube inspection, maintenance personnel may inspect the lube every two months for the first year of operation. The condition of the lubrication may in fact indicate that inspection this is too frequent and unnecessary. If sealed correctly and covered sufficiently, the bearing lube could last for several years. Synthetic base lubricants can last up to five times that of the conventional based equivalent.

Conclusion

A successful bearing installation completes what was most likely several years of planning and design of a new or rehabilitated moveable bridge. With the increasing costs of construction and manufacture it makes sense to pay particular attention and care for those more costly components like large bearings. The bearing manufacturer should be consulted at each step along the design process and be intimately involved in all aspects related to the moveable bridge bearings. This will ensure that all things are considered and help to achieve years of successful bearing performance.