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Technical Discussion: Propeller Shaft Bearings

The following is an article on the aspects of propeller shaft bearing to include design, theory, quality, mil spec, maintenance and replacement:

BASIC BEARING DESIGN

The surface of a rubber-lined bearing is divided by water grooves into a number of lands or faces. These surface lands run parallel to the shaft and serve to support it. A tough resilient rubber compound is provided which is relatively immune to the action of grit and sand. It also helps reduce noise and vibration, while protecting the shaft from undue wear.

HOW DOES THE BEARING WORK?

A water-lubricated bearing must have water flowing through it continuously when operating. With proper loading, rotational speed, clearances and alignment, the shaft will carry a film of water as it rotates. This film of water actually lifts the shaft, and the shaft then “rides” on the water film. This is called hydrodynamic lubrication. When it is achieved, both friction and wear are very low.

If a grain of sand enters the bearing and gets trapped between the shaft and the rubber lining, it is depressed into the rubber and rolled into a water groove where it is flushed out of the bearing minimizing damage to the bearing and shaft.

QUALITY

- Cutless bearing outside diameters are finish machined, by turning on inside diameter mandrels. This assures excellent concentricity. Centerless-ground bearings may have a very round and finely ground finished outside diameter, but there is no relationship between the inside and outside diameter of the part. Therefore, concentricity may be poor.

- Cutless bearing inside diameters are typically molded and finish machined to assure compliance with published/industry standard clearances.

- Not all Cutless bearings are listed on the Qualified Product List for U.S. Military Specification MIL-B-17901B (SH)/AMD-3 Class II. MIL-B-17901B contains very stringent requirements including: wear test requirements (for both bearing and shaft), adhesion tests, and rubber swell tests.

MIL-B-17901B TESTING AND APPROVAL

Cutless brass-shelled, fully molded (Class II) bearings exceed the very demanding requirements of U.S. Navy MIL-B-17901B. MIL-B-17901B defines specific physical property requirements for the rubber bearing material. The physical requirements include:

- minimum and maximum levels of hardness
- tensile strength
- yield strength
- water and oil absorption
- rubber surface finish

In addition to the physical requirements, performance testing is done to measure the bond strength of the rubber to the shell. These tests are performed before and after water, heat and oil soaking and thermal cycling.

Performance tests are done to determine bearing wear. Both the bearing and journal wear in gritty water are measured (system wear). Very few bearings are capable of passing the tests required by this military specification! Duramax Marine is the only manufacturer who is on the Qualified Products List for fully molded (Class II) bearings. Other bearing manufacturers do not meet the full specification.

PERFORMANCE: TOTAL SYSTEM WEAR & COST

When considering bearing wear and replacement, the wear of the total system (bearing and journal) should be taken into account. Most wear generally occurs at start up and shut down when the hydrodynamic lubricating film is not fully developed. As the shaft speed increases, a hydrodynamic water film begins to form and friction decreases significantly. Once sufficient journal surface velocity has been reached (the textbook definition is 1 meter per second) a hydrodynamic water film is formed and the shaft rides on the thin film of water. At this stage, the coefficient of friction is very low and both wear and frictional heat are reduced to a negligible amount. The enclosed diagram shows the stages of lubrication. When there is high friction, both the bearing and journal will wear.

General Information

STORAGE OF CUTLESS BEARINGS

Cutless Bearings should be stored in their original boxes away from elevated temperatures, exposure to high ozone concentration and direct sunlight (ultra violet), fluorescent light or chemicals. Possible areas of high ozone concentration are near electrical arcing devices or any welding process.

SHELF LIFE OF CUTLESS BEARINGS

The normal shelf life of Cutless Bearings is five to ten (5-10) years, provided they are stored in a cool place, away from heat, direct sunlight, fluorescent light and electrical arcs which can generate ozone.

All of our brass and non-metallic shell sleeve bearings have a Julian date of manufacture marked lengthwise along the outer shell of the bearing along with the words "Made in the USA" and the part number. (Code GOLD is marked on the end of the bearing shell and slim line bearings are not stamped on outside diameter of part). Flanged bearings have the information stamped on the flange.

As the shelf life can vary due to the above factors, it is best to visually check stored bearings before using. Look for cracks in the rubber, which may show up in the water grooves and for bond separation between the rubber and the shell on the ends. If either of these conditions exists, the bearing has experienced age hardening and, although it may be functional in the short term, should not be used. Any questionable bearing should be returned to the factory for inspection and evaluation.

INSTALLATION OF NAVAL BRASS SHELL CUTLESS BEARINGS

Sleeve Bearings

In marine applications, Cutless Sleeve Bearings are generally installed in a housing with a light press fit and held in place by cone point set screws. Often a second setscrew is installed on top of the first to lock the first setscrew in place. The bearing shell is spotted to receive the setscrews in such a manner as to prevent them from extending through the shell into the rubber and thus forcing the rubber against the shaft. This permits the setscrew to prevent movement of the bearing without requiring the screw to be so tight that distortion of the bearing could occur.

Flanged Bearings

Flanged type bearings should be installed with a light press fit and secured by suitable studs and nuts through the flange. Code name flange bearings are supplied with the flange “undrilled”. The flanges are drilled in the field to match the bolt pattern on the ships hull or bulkhead. If flange will not be secured, the use of setscrews is recommended.

Press Fit/Shrink Fit

Chilling sleeve and flanged bearings before fitting is an acceptable practice to achieve an interference fit between the bearing shell and housing. The method of chilling must be slow and mild in temperature (no lower than 0°F) and the interference fit light. If the chilling is fast with extreme temperature drops, the thermal shock can result in the separation of the bond between the rubber and metal shell. ***Never use dry ice to cool a Cutless Bearing.*** The interference fit between the outside diameter of the bearing and the inside diameter of the housing should not be more than a light press fit. Chilled bearings should be pressed into the housing, not pounded. Pounding a chilled bearing can create sufficient shock to separate or break the metal to rubber bond.

Reinstallation of the Shaft & Installation Lubricants

Use care in installing heavy shafts. In the case of large and heavy shafts, use a mild water-soluble soap on all bearings. ***Never use petroleum-based lubricants.*** Non-water-soluble lubricants can leave a residue that can restrict water flow. Glycerine is a suitable lubricant to use when installing shafts. Care must be taken to prevent tearing the rubber lining when the shaft is inserted into the bearing. The weight of the shaft should be properly supported during the process.

INSTALLATION OF CUTLESS NON-METALLIC BEARINGS

This procedure includes steps for removal of a worn out non-metallic Cutless bearing. If this is new construction, begin this procedure with step 6.

Sleeve Bearing Removal

1. Read all of these instructions before beginning work.
2. Locate all of the setscrews holding the old bearing in place. Remove these screws.
3. Check each setscrew location for a second setscrew. A second setscrew is often used to lock the first one in place. If there are second setscrews, remove them.
4. The bearing can now be pressed out of the strut. If removal is difficult, the bearing can be cut into sections. ***Be careful not to cut the bearing housing*** and remove <u>all</u> pieces of the worn bearing.
5. If the shaft has been removed, the strut housing should be honed to remove all dirt, corrosion, and foreign material. A brake hone is good for this purpose. Clean all dust and small particles from the housing after honing. If the shaft is in place, the housing should be polished the best way available. One way would be the use of strips of abrasive cloth. Sanding dust should be blown out of the housing with compressed air. Do not sand blast inside of housing to clean. Bearings typically require a smooth housing ID. Sand blasting leaves a roughened surface.

Installation of New sleeve Bearing

6. The bearing should fit the housing with a light press fit. Do not lubricate the inside of the housing or the outside of the bearing shell. If installation is difficult, the bearing may be slowly cooled using a freezer or conventional ice for a minimum of 2 hours before installation. ***Never cool below 0 degrees F. Never use dry ice. Never pound or shock the bearing while it is cooled.*** This may cause the rubber to separate from the shell.

7. After the bearing is pressed into the strut or housing, prepare the bearing shell for setscrews by drilling the bearing shell through the center of the tapped setscrew holes in the strut. Drill part way through the shell only. ***Do not drill into the rubber.***

8. Use a wrench to tighten the setscrews "finger tight".

9. A second setscrew can be installed in each tapped hole to lock the first setscrew in place. Tighten using the long leg of the Allen wrench. This will keep the first screw in place.

10. The bearing is now installed. If the shaft is not in place, check the bearing for dirt or other foreign material and clean it before installing the shaft. If the shaft is already installed, the bearing should be blown out with compressed air.

11. With the transmission in neutral, try to turn the propeller by hand while the shaft is supported. It should turn freely without any binding or rubbing in the bearing.

12. Lower the shaft so that it is just touching the bottom of the bearing without compressing the rubber. Using a feeler gauge, check the clearance between the shaft and the bearing at a point 180 degrees opposite the location where the shaft touches the bearing. If the shaft is touching the bearing at the 6 o'clock position, the clearance should be measured at the 12 o'clock position.

INSTALLATION OF SHAFT INSTRUCTIONS

To facilitate shaft installation without damage to the rubber bearing surface; bearing surfaces should be lubricated prior to shaft installation. This can be accomplished with a detergent and water solution or any other water-soluble lubricant such as Rub Lube. It should be an unadulterated product that does not contain acids, ammonia, chlorine or any other harmful additive. Glycerin may be used.
CAUTION: Although the rubber is oil resistant, never use oil, grease, or any petroleum-based or non-water-soluble substance as a lubricant. It may block water flow and pollute the environment.

MAINTENANCE OF INSTALLED CUTLESS BEARINGS

Cutless Bearings must be thoroughly lubricated with water whenever the shaft is in operation. We recommend a minimum lubricating water flow of 2 gallons per minute per inch of shaft diameter at 5-7 psi over static head pressure for forced lubricated bearings. (For example, a 4-inch journal would require at least a flow of 8 gpm).

To assure long service life, Cutless Bearings must be protected from compression set. Compression set occurs when rubber sustains a prolonged concentrated load. Properly supporting the shaft during storage, so that the rubber bearing faces are not compressed by the shaft, prevents this type of distortion. If the shaft cannot be supported with proper equipment, we recommend rotating the shaft periodically (minimum once every week) to remove sea growth. Rotation is defined as turning the shaft at least 450 degrees so the shaft is not sitting continuously in one spot. The shaft and bearings must have lubrication present (glycol solution or Rub-Lube is acceptable) when rotating the shaft. ***Never use petroleum-based lubricants on Cutless bearings.*** Good circulation of water throughout the bearing is essential for proper lubrication and to keep temperatures at an acceptable level during operation.

RULES FOR MAINTAINING GOOD BEARING LIFE & PERFORMANCE

1. Nominal loading should not exceed 40 psi.

2. Shaft surface velocities should be in excess of 3.25 feet/second to maintain a hydrodynamic water film to minimize frictional heat generation and wear.

3. Proper clearances are needed to offset potential shaft misalignment and moderate environmental temperature increases. This is to support water film formation. If poor bearing installation should occur, shaft clearance measurements can serve as a warning signal.

4. Good circulation of water lubricant is needed (2 gallons per minute per inch of shaft diameter), not only to develop the water film but also to dissipate frictional heat, and flush out foreign matter.

Should the design circumstances require violation of any one of the first three rules, the bearing design criteria would require strong consideration for forced lubrication. **Rule 4 must not be violated at any time.** Water lubrication interruption to any rubber bearing will generate rapid frictional heating and failure.

Loading, shaft speed, clearances and lubrication flow all have a drastic effect on the life of a bearing. None of these four rules can be ignored or abused without consequences.

FACTORS THAT AFFECT BEARING LIFE

1. Bearing load
2. Bearing clearance
3. Surface velocity / time interactions
4. Time at zero velocity
5. Total operating time
6. Shaft and bearing roughness
7. Uniformity of loading
8. Shaft and bearing materials
9. Bearing alignment
10. Winter lay up on shore
11. Availability of lubricating water
12. Type and amount of abrasives in water
13. Condition of propeller – unbalanced, cavitating, other