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The impact of preload in journal bearings

Preload is a term used in several mechanical systems. Usually, in practical terms, it refers to a loading of a device at installation. For instance, flexible element couplings are sometimes preloaded (prestretched) so when the machine reaches thermal equilibrium the coupling operates near its neutral position. With angular contact ball bearings, preloading is the loading of the bearings without the application of an external force. Preloading of angular contact bearings allows more exact and rigid rotor positioning and helps prevent skidding at low loads. Preloading of fluid film journal bearings is a little different.

Fluid Film Operation in Journal Bearings

Without getting too deep into hydrodynamic bearing operation, we do need to briefly discuss how a sleeve or tilt pad journal bearing operates. These bearings have clearance over the journal and the rotation of the shaft drags oil into the space between the journal and the bearing. As the oil is dragged into the load region of the bearing, the space available diminishes and the oil is squeezed out. This squeeze action causes pressure to build in the oil film which, when integrated over the journal surface, equalizes with the load on the bearing. Figure 1 is a drawing of a sleeve bearing showing this pressure build up. The action is very similar in a tiling pad bearing except the pad tilts to obtain the attitude angle.

"The formula for preload is: $m=1-(C_b / C_p)$"

It is also important to note that if the journal is centered in the cylindrical bearing there is no converging region and the bearing will not develop any appreciable load capacity.

Preload With Elliptical Bore Sleeve Bearings

As we can see from the discussion above the whole premise of hydrodynamic lubrication is based on the converging oil wedge. If we can optimize this wedge, we can optimize the bearing. A look at elliptical bore journal bearings will help illustrate this.

Elliptical bore bearings are more stable than plain sleeve bearings because they offer a steeper converging wedge. This is accomplished by manufacturing the bearing with an elliptical bore; the vertical bore is smaller than the horizontal bore. This is accomplished by finishing the bore of the bearing with shims at the bearing split line. The bearing is bored to the desired horizontal dimension and shims are sized to yield the desired vertical bore when they are removed. The resultant bore is lemon shaped and referred to as elliptical. Preload is a measure of the difference between the vertical and horizontal clearance of the bearing. The formula for preload is: $m=1-(C_b/C_p)$, where m = preload, C_b=bearing clearance (vertical), and C_p=pad clearance (horizontal).

Figure 2 is a drawing of an elliptical bore journal bearing. Note that for the case shown the shaft size is 6.000 inches, the vertical clearance is .009 inches and the horizontal clearance is

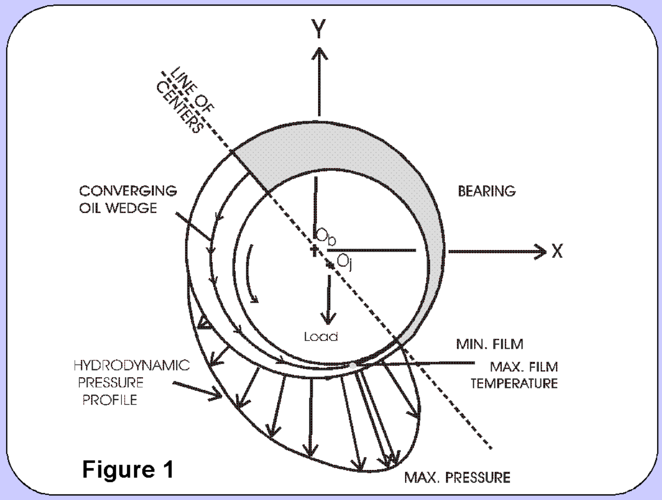

Figure 1

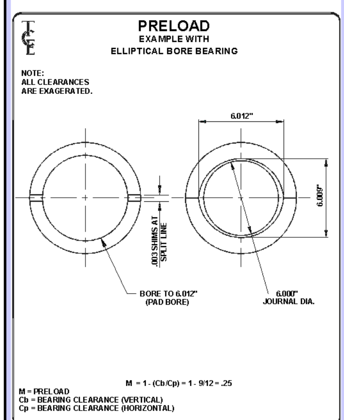

Figure 2

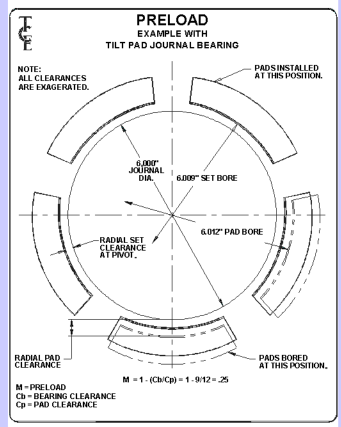

Figure 3

.012 inches (this works out to a 0.25 preload). The vertical clearance is often referred to as the bearing clearance, the set clearance, or the assembled bearing clearance. To obtain this bore the bearing is finish machined to a 6.012 bore with 0.003 inches shims at the split line. When these shims are removed the vertical bore is 6.009 and the horizontal is 6.012. However the curvature of the bearing is 6.012, this makes the converging portion of the bearing steeper. A common preload for elliptical bearings, especially ring-oiled bearings, is 0.5.

Preload with Tilting Pad Journal Bearings

The description above should help to explain the preload of tilting pad journal (TPJ) bearings. Most TPJ's are designed to have some preload; the range is usually 0.25 to 0.50. Manufacturing the preload into TPJ's is no longer a simple matter of shimming the bearing. Now we have several pads (usually 4-7) which need to have a curvature larger than the bearing's assembled bore. This is done by boring the pads in a pot. A pot is a fixture that holds all the bearing pads for boring. With rocker back journal bearings, the bore of the pot will be larger than the bore of the housings that the pads will be assembled into. The amount the pot bore is larger than the bearing housing bore

Continued on Page 2

Preload

Continued from Page 1

determines the amount of preload.

The drawing in figure 3 should help to clarify this. Note that the example is a 6.000-inch shaft and we want a 6.009 set bore with a 0.25 preload. Of course, this means the bore of the pads needs to be 6.012. For this, we assemble the pads into a pot that has a bore that is 0.003 larger than the housing bore that the pads will be assembled into. The difference between the pad bore and the shaft diameter is referred to as the diametral pad clearance (C_p). The difference between the assembled bearing bore and the shaft diameter is the diametral bearing clearance (C_b). This clearance is always taken at the pivot point of the pad.

Why Preload?

Preload is a powerful design tool for the bearing designer. It gives another factor, which can be manipulated to optimize the bearing. For most TPJ's low preload values are desired. This is because, generally speaking, as preload increases damping decreases. Usually it is a design goal to maximize damping. Negative preloads, however, need to be avoided because they can cause significant, undesirable, changes in stiffness and damping terms.

Preload is preferred in vertical applications since these bearings see minimal applied loads. The hydrodynamic loading of preloaded pads will activate stiffness and damping in the bearing and thus help to suppress vibration.

Lastly, preload is beneficial when it allows normally unloaded top pads to become loaded, hydrodynamically, and therefore can contribute to the overall stiffness and damping of the bearing. In addition, some upper pads in large TPJ's (14 inches and above) can flutter if not loaded against the bearing shell by preloading the pad bores, this pad flutter can significantly damage the pad.

Conclusion

This is a very brief introduction to the concept of preload as found with fluid film journal bearings. We attempted to describe how preloading works, how it is obtained in the manufacture of bearings and how it may impact bearing performance.

Squeeze film damper bearings help machine run smoother

Our featured paper this quarter is *The Design and Application of a Squeeze Film Damper Bearing to a Flexible Steam Turbine Rotor*. The paper discusses a critical multistage steam turbine in a large chemical plant that experienced high vibration levels and frequent repairs. A rotor dynamic analysis revealed that the rotor was highly sensitive to unbalance. A combination tilting pad journal bearing encased in a squeeze film damper was proposed and accepted along with the addition of two nonfunctional dummy wheels that lowered the first critical speed, thus improving the separation margin. When the machine was started after these changes, the rotor amplification factor went from 14.8 to 3.2 with greatly reduced vibration amplitudes throughout the operating speed range. This machine has been running well for more than five years and has survived many startups and shutdowns without incident. Please send us an E-mail or give us a call if you would like a copy of this paper.

Meet the TCE team

Alan Stephenson

Another member of the TCE team is Alan Stephenson. Alan joined TCE in 1997 bringing with him a total of 19 years experience in the turbomachinery parts business. Alan began his career with Centritech in 1981 and worked in production, sales, estimating, and operations coordination throughout the 80's and 90's. Alan was Product Production Manager for Babbitted Bearings and Seals at Turbocare. With his product knowledge, technical expertise, and attention to detail, Alan manages the inside sale function, quotation estimating, and procurement of purchased finished materials and long lead time materials. Outside of TCE, Alan has a Mobile DJ business, enjoys fitness training, coaching his kids city sports leagues, and outdoor activities.

Recent Orders of Note

1. Performed RDA on a blower and converted from a pillow block sleeve bearing design to a ball & socket tilt pad journal bearing. This was accomplished by modifying the existing housings.
2. Refurbished hydrogen seals and all journal and thrust bearings for a 140 MW steam turbine generator set, on a rush basis.
3. Worked with Kaydon Ring and Seal on rebuilding six Kaydon seal assemblies for three ammonia compressors.
4. Engineered, designed, manufactured, and installed Torlon seals in two barrel Compressors.
5. Manufactured four custom designed ball and socket tilt pad journal bearings. These are the #1, #2, #3 and #4 bearings in a 1,000 MW turbine generator set, they ranged in size from an 11-inch bore to a 17-inch bore.

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