Troubleshooting Tilting Pad Thrust Bearings

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Plain bearings are generally durable and operate for long periods with little or no interruption. However, like all mechanical systems, the bearing conditions periodically degrade. A rigorous failure analysis approach will help the bearing operator understand the failure modes and mechanisms, and find ways to achieve longer operating cycles.

A structured bearing troubleshooting approach based on an understanding of bearing operation and the potential effects of related parameters exists. Of particular interest are the rotating journal, collar or runner, the babbitted (metal alloy) shoe surface, all contact points within the bearing assembly and the lubricating oil. Machine-specific operational and performance data must also be considered.

Figure 1. Leading Edge Groove (LEG) Thrust Bearing

The approach discussed here is centered on equalizing thrust bearings. These bearings contain the most moving parts and are widely used. The lubrication and troubleshooting principles are readily adaptable to other fluid-film bearing types (nonequalizing thrust bearings, pivoted shoe journal bearings, journal shells).

When evaluating bearing distress, the babbitted shoe surface is commonly the only area that is examined. Although a great deal of information can be extracted from the babbitt appearance, additional information exists elsewhere. These secondary sources of diagnostic information often prove to be valuable, because the babbitted surfaces are usually destroyed in a catastrophic bearing failure. Even a bearing wipe, which is the most common appearance of distress, may hide valuable information.

The textbook cases of distress modes are especially useful in diagnosing problems prior to the damage that occurs when a bearing can no longer support an oil film. Through the prudent use of temperature and vibration monitoring equipment, routine oil analyses, lubrication system evaluations and machine operational performance reviews, bearing

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distress may be identified and evaluated before catastrophic failure occurs.

Bearing health is commonly monitored through the use of temperature measurements. Be aware that temperature sensors may be mounted in a wide variety of locations, with a corresponding variation in temperature. The specific location and type of sensor must be known in order for the measured temperature data to have any real value.

Inspection Sequence

To begin an evaluation, the bearing assembly should be completely disassembled. All bearing components may be evaluated in this manner. Do not clean the bearing, because valuable information may be lost.

Base Ring

Examine the base ring. During routine operation, the lower leveling plates may form indentations in the base ring, on either side of the dowels that locate them. The indentations should be identical and barely noticeable. Deep, wide indentations are an indication of a high load. The rocking strip on the bottom of the lower leveling plates contacts the base ring, and its condition presents another indication of bearing load.

The cleanliness of the bearing and oil can also be determined, because deposits are often trapped in the base ring. Evidence of water contamination, particularly in vertical machines, may go unnoticed unless the base ring is examined.

Figure 2. Thrust Shoe Surface Abrasion

Leveling Plates

The spherical pivot in the rear of each thrust shoe rests in the center of a flat area on the hardened upper leveling plate. This flattened area is susceptible to indentation due to the point contact of the pivot. The indentation is easily identified by a bright contact area. This area indicates where the shoe operates on the upper leveling plate, and its depth gives an indication of load. Close examination of the upper leveling plate near the contact area may also produce evidence of electrical pitting.

The upper leveling plates interact with the lower leveling plates on radiused wings. The upper leveling plates are typically hardened; the lowers are not. When new, the leveling plates have line contact. There is little friction between the wings, enabling the bearing to react quickly to load changes. Depending on the nature and magnitude of the thrust load, the wing contact areas will increase in time. The contact region of the wings, again noted by bright areas, will normally appear larger on the tower leveling plates. If the rotating collar is not perpendicular to the shaft axis, the leveling plates will continuously equalize, causing rapid wear.

Shoe Support

The shoe support is the hardened spherical plug in the rear face of each thrust shoe. Based on the magnitude and nature of the thrust loads, the spherical surface will flatten where it contacts the upper leveling plate. The contact area will appear as a bright spot on the plug. If evidence of hard contact exists (a large contact spot), rest the shoes (pivot down) on a flat surface. If the shoes do not rock freely in all directions, they should be replaced.

The pivot can also appear to have random contact areas, indicating excessive end play, or it may be discolored, indicating lack of lubrication.

Shoe Body

The shoe body should be periodically examined for the presence of displaced metal or pitting. Indentations routinely occur where the shoe contacts the base ring shoe pocket in the direction of rotation. Displaced metal, exhibiting a coarse grain, may indicate erosion damage. Bright or peened spots may indicate unwanted contact. Depending upon the shape of the individual pits, pitting may indicate corrosion or undesirable stray shaft currents.

Shoe Surface

When evaluating the shoe surface, the first step should be to determine the direction of rotation. This may be accomplished by evaluating:

- Abrasion scratches
- Discoloration (75-75 location)
- Babbitt flow
- Babbitt overlay
- Thrust shoe/base ring contact

Use caution when evaluating babbitt overlay (babbitt rolled over the edges of the shoes), because it may appear on both the leading and trailing shoe edges.

Normal

A healthy shoe will exhibit a smooth finish, with no babbitt voids or overlays. The dull gray finish of a brand new shoe may remain unchanged after many hours of operation, or it may appear glossy in spots or in its entirety. Routine thermal cycling of the bearing may cause the emergence of a mild starburst or mottled pattern in the babbitt. This is harmless, providing the shoe is flat and cracks do not exist.

Scratches

Abrasion

Abrasion damage will cause a bearing surface to exhibit circumferential scratches (Figure 2). Abrasion is caused by hard debris, which is larger than the film thickness, passing through the oil film. The debris may embed itself in the soft babbitt, exhibiting a short arc on the shoe surface, ending at the point the debris becomes embedded. Depending on the debris size, the scratch may continue across the entire shoe surface.

Abrasion damage becomes worse as time progresses. Surface scratches allow an escape for lubricating oil in the oil wedge, decreasing the film thickness. This will eventually lead to a bearing wipe.

Another source of abrasion damage is a rough journal, collar or runner surface. Roughness may be due to previous abrasion damage. It may also be from rust formed after extended periods of downtime. New bearings should not be installed when the rotor is visibly damaged.

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Figure 3. Tin Oxide Damage

Figure 4. Thermal Ratcheting

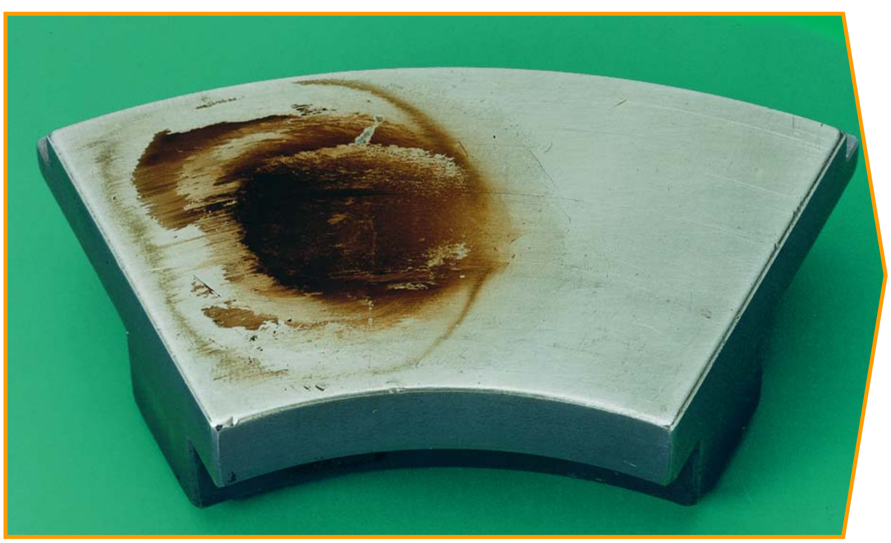

Figure 5. Overheating Oil, Additives Plated Out

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Random scratches, which may run a staggered path both circumferentially and radially, are more likely to appear in the unloaded bearing or unloaded portion of the bearing. In a thrust bearing, it may indicate excessive end play (axial clearance). Random scratches may also indicate careless handling at installation or disassembly.

To eliminate abrasion damage, the lubricating oil must be filtered. If the oil cannot be filtered or has degraded, it should be replaced. It is important to evaluate the filtering system, because the problem may be an incorrectly sized filter. The filter should pass only debris smaller in size than the predicted bearing minimum film thickness.

In addition to filtering or replacing the oil, the entire bearing assembly, oil reservoir and piping should be flushed and cleaned. The original bearing finish should also be restored. Journal shoes typically must be replaced, but if the correction leaves the bearing within design tolerance, the bearing may be reused.

Although the babbitted surface is usually damaged more severely, the rotating collar or journal surface must also be evaluated. Debris partially lodged in the babbitt may score the steel surfaces. These surfaces must be restored by lapping or hand stoning.

Discoloration

Tin Oxide Damage

Tin oxide damage is one of several electrochemical reactions which eliminate the "embedability" properties of a fluid film bearing. It is recognizable by the hard, dark brown or black film that forms on the babbitt (Figure 3).

Tin oxide forms in the presence of tin-based babbitt, oil and salt water, beginning in areas of high temperature and pressure. Once it has formed, it cannot be dissolved, and its hardness will prevent foreign particles from embedding in the babbitt lining.

This damage may be stopped by eliminating some or all of the contributing elements. The lubricating oil must be replaced. A reduction in oil temperature may also discourage the formation of tin oxide.

In addition to replacing the oil, the entire bearing assembly, oil reservoir and piping should be flushed and cleaned with mineral spirits. The bearing shoes should be replaced. The condition of the rotating journal, collar or runner surfaces must also be evaluated. They must be restored to original condition, either by lipping, hand stoning or replacement.

Overheating

Overheating damage may represent itself in many ways, such as babbitt discoloration, cracking, wiping or deformation. Repeated cycles of heating may produce thermal ratcheting, a type of surface deformation that occurs in anisotropic materials (Figure 4). These materials possess different thermal expansion coefficients in each crystal axis.

Oil additive packages may plate out at relatively high bearing temperatures. The plating typically begins in the area of highest temperature, the 75-75 location (Figure 5).

Overheating may be caused by numerous sources, many of which concern the quantity and quality of the lubricant supply. Possible causes include:

- Improper lubricant selection
- Inadequate lubricant supply
- Interrupted fluid film
- Boundary lubrication

The following conditions may also cause overheating:

- Improper bearing selection
- HP lift system failure
- Poor collar, runner or journal surface finish
- Insufficient bearing clearance
- Excessive load
- Overspeed
- Harsh operating environment

It is important to verify that the quantity and quality of oil flowing to the bearing is sufficient. These values should be available from the bearing manufacturer.

If thermal ratcheting has occurred, examine the shoes for the existence and depth of cracks. Remove the cracks and restore the original shoe surface. If this cannot be done, replace the shoes. Journal shoes typically must be replaced, but if the correction leaves the bearing within design tolerance, the bearing may be reused.

The condition of the rotating journal, collar or runner surfaces must also be evaluated. It must be restored to original condition, either by lapping, hand stoning or replacement. ML