BEARING SPECIFIC TOPICS

BEARING INDUSTRY INFORMATION

Wear Sleeves & Other Shaft Repair Options

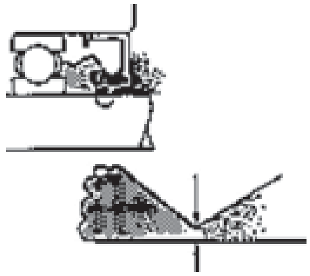
Fluid leakage in mechanical systems can be experienced even when using what appear to be properly prepared shafts. Before replacing a seal to correct a leakage situation, it is essential that all aspects of the shaft that it runs on be also considered. Factors such as surface finish, dimensional accuracy and operating conditions can all effect seal performance. Advances in seal design and materials have extended seal service life and reliability. However, these are of no benefit to endusers if the shaft fails to provide a quality countersurface for the seal lip to run on.

How a radial lip seal functions:

Rubber lip radial shaft seals work by creating a “pumping” action in the narrow contact zone where the seal lip interfaces with the shaft (typically .010 - .020” wide after break-in). This maintains a controlled fluid film (about 0.00001” or .25 microns thick) under the lip and retains system lubricants while excluding contamination.

What is an “ideal” shaft for a lip seal?

Industry testing and experience have shown that the following characteristics provide the recommended shaft for lip seals:



- Roughness. In general a surface roughness of Ra 9 - 17 micro inches (.23 -.43 micrometers) (Per the Rubber ManufacturersAssociation) results in optimum seal performance. Certain operating conditions such as a vacuum, dry running and seal lip materials like Teflon® may require a smoother or different surface
- Shaft lead. Outward spiraling or “lead” patterns on a shaft are highly correlated with early leakage. Regardless of shaft finishing method, lead angle should be <0 ± 0.05 degrees. Any relative axial movement between the shaft and a finishing device (i.e. centerless grinding, paper polishing) can create lead. Therefore centerless grinding to spark-out is recommended to avoid the grooving effect of lead. A simple string test or use of electronic tracing instruments can establish the presence of lead. It should be emphasized that directionality or lead on the shaft surface is more influential on leakage control than roughness.
- Hardness: A hardness of 30 HRc or more reduces the chance of nicks and scratches caused by contact damage during handling and installation. Harder shafts are also better able to resist abrasive grooving in areas of high contamination.

- Texture: Some seal users have found leakage even on properly finished shafts within the standard specification. However, the Ra measurement of surface roughness does not fully characterize the shaft surface. Two shafts with identical measured roughness (Ra is an averaging formula) can have very different surface profiles or textures. New research has shown that shafts with a good smoothness value but with deep valleys can create leakage. This is because the volume of oil in the valleys can overcome the pumping capability of the lip seal. Obvious or premature seal wear may not be noted to account for the loss of fluid control. Surface specifications of Rz (avg. peak to valley height) of 65-115 μin (1.65-2.92 μm) and Rpm (avg. peak to mean height) of 20-50 μin (.51-1.27 μm) are recommended to avoid this problem.

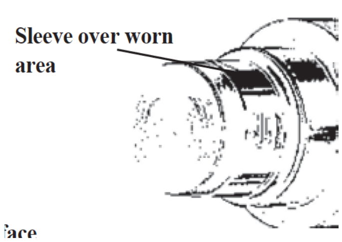
Summary: Concurrent adherence to the recommended Ra, Rz, Rpm and shaft lead values must be observed to minimize leakage. These and other details for common shaft seals are summarized in the chart on page 3. Also, lip seals with hydrodynamic lip patterns (diamonds, crescents, waves or vanes) are less sensitive to shaft lead and finish than plain trimmed lips.

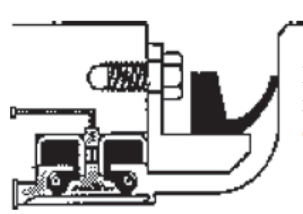
A rubber lip seal is a friction device, and conditions like shaft-to-bore misalignment can cause the oil film between lip and shaft to squeeze out, resulting in direct contact. Eventually shafts develop wear grooves simply from normal seal wear, especially in abrasive environments.

Options for repairing worn or damaged shafts

1. Replace the shaft. Can restore “like new” performance. Depending on accessibility, the work to completely remove and replace a shaft can be costly. Besides the price of new hardware, labor and lost production time may not be acceptable.
2. Repair (metalize and regrind). In this alternative, the labor price to remove and replace the shaft will be the same. However, metalizing, machining and transportation costs must be added in, and the equipment downtime will be longer. And the refinished area must be carefully inspected for conformance to specification.
3. Remachine the shaft. Similar in costs and benefits to option 2. As explained, the machining must be carefully done. However usually enough stock has to be taken off that a new seal with a smaller inside diameter is necessary, or a specially machined, thick-walled wear sleeve must be used. This requires more inventory, complicates field service and, unless sleeved, the operation can only be done once.
4. Reposition the seal. This might be an option if the machine has a through bore and the seal was originally installed flush with the housing. Simply position a new seal further into the bore. This interior zone should have been protected from rust and damage. However its suitability as a sealing surface has to be confirmed and repositioning usually works only once.
5. Use a shaft repair sleeve A shaft repair sleeve has the potential to instantly restore a worn or damaged shaft or create an original, high quality seal surface. Sleeves are usually used with shaft diameters from .500 to 8.00” (12.7 to 203.2 mm). Most have a flange and are intended to be driven on with a simple tool or press. Wall thicknesses vary. Thin-walled sleeves (about .011” or .279mm) thick do not add enough to the shaft diameter to require a different seal inner diameter size. For thin-walled sleeves, basic shaft preparation consists of removing burrs and filling deep grooves.

Note: The installation end of the shaft must be reachable and these thin sleeves are not recommended to pass over splines, keyways or ports at the nominal shaft diameter. Sleeves with wall thickness above .030” (.76mm) add too much interference, and a new seal of appropriate size must be selected. Most sleeves above 8.00” (203.2mm) have wall thickness of .060” (1.52 mm) or more. Not only do they require shaft grinding or changing the seal size, but may require a heated slip-fit (to approx. 350 °F in a bearing heater or similar) must be used at assembly. They do preserve the main benefits of shaft repair sleeves, which are speed and repeatability.





Heavy-walled sleeve installed in rolling mill equipment.

Seal Interface

- “Interface is the point of contact between sealing surfaces.
- Surfaces must be separated by a film of lubricant 0.00001 in. thick - one hundred thousandth of an inch (0.25 microns).
- Lube prevents rapid wear of seal lip and shaft surface.
- Lose tolerances keep lubricant from leaking.
- Avoid uncontrolled conditions of runout, misalignment or eccentricity.

Note: Interface is a very important concept to emphasize. Too much interference between the seal lip and shaft surface created excess heat and serious seal damage. Too little interference causes lubricant to leak from the bearing cavity.

Large Diameter Wear Sleeves

Design/construction:

- Provides positive sealing surface often better than original.
- Repairs seal worn shafts over 8” (203 mm).
- Made from cold rolled steel (SAE 1005-1020).
- May be hard chrome-plated 0.0015” to 002” (0.0381 mm to 0,0508 mm) thick; B96 Rockwell hardness.
- Machined to provide a high quality count
  Style 3 sleeve:
- With flange for pull-on installation of heated sleeve.
  Style 4 sleeve:
- Used where space restrictions limit width, prohibit use of flange.

Be sure to install with chamfer facing seal mounting direction.

Note: For additional wear sleeve instructions, consult your wear sleeve provider.

Size specifications:

- Wall thickness of 0.094” adds 0.188” (4.78 mm) to shaft diameter.
- Any size to fit shafts 8” to 45” (203 mm to 1250 mm).

Shaft Lead Detection: Suspended Weight Method

Shaft Lead: Spiral grooves can be generated on a shaft surface by the relative axial movement of the finishing tool (grinding wheel, belt, lathe) during the finishing operation. This condition, known as shaft lead, can have an effect on the sealing properties of a mating radial lip type oil seal. Lead may be detected and quantified by partially wrapping a thread about the leveled shaft with a subtended, relatively light weight and slowly rotating the shaft. If the thread transverses back and forth as the direction of rotation is reversed, shaft lead is present.

Equipment to Detect Shaft Lead: The shaft can be checked for lead by chucking it in a lathe that can be reversed. Special test machines can be constructed with small, reversible, variable speed electric motors to drive the test pieces. In some cases, the unit has been mounted on a comparator. The surface of the shaft and the thread appear greatly magnified on the screen of the comparator. This magnified view is helpful in determining the rate of thread advance when the shaft is rotated.

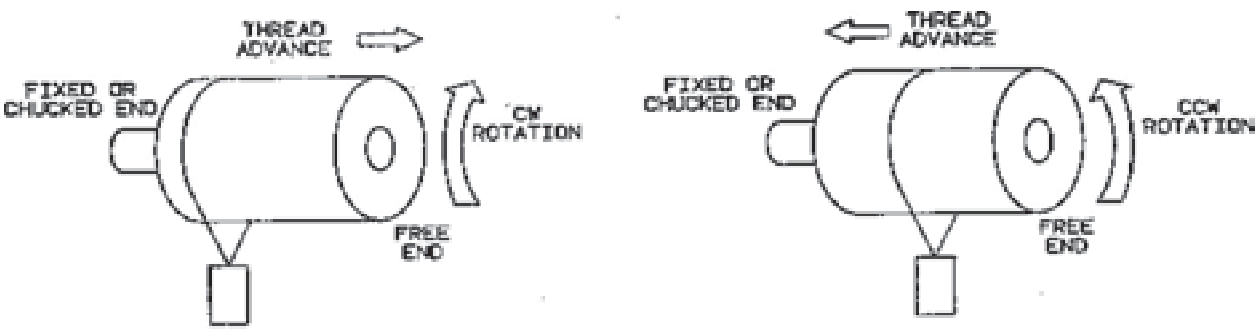
Procedure to Detect Shaft Lead:

1. Mount shaft or sleeve in holding chuck and lightly coat with silicone oil. The viscosity of the oil is 5 to 10 cps.
2. Check and adjust the level of the setup. For best results, the shaft should be level.

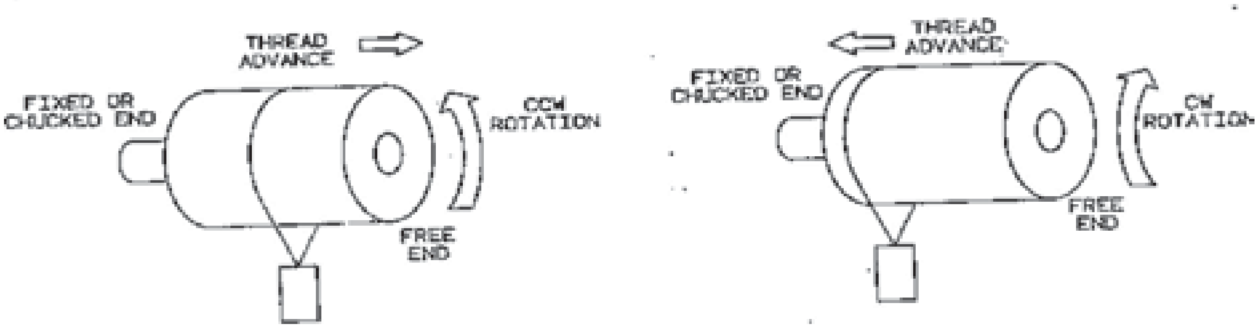
1. A thread* (100% extra strong quilting thread .009 inch (0.23 mm) diameter is recommended) is draped over the surface of the shaft and a one ounce (30 gm) weight is attached at a distance below the shaft to create a string-to-shaft contact arc of 220 to 240 degrees.
2. Adjust rotational speed to 60 RPM.
3. Observe the axial movement of the thread while the shaft rotates. Reverse the direction of shaft rotation. Place the thread both at the center and edges of the shaft to observe for movement.
4. It is recommended that the thread be changed after checking 100 shafts.
5. *Unwaxed dental floss may be substituted.

Interpretation of Results

1. CW or right hand lead: The thread will advance from the fixed or arbor end of the shaft towards the free end whenthe shaft is rotating clockwise (CW). The thread will move from the free end of the shaft towards the fixed end for counter clockwise (CCW) rotation. See A below.



2. CCW or left hand lead: The thread will advance from the fixed or arbor end of the shaft towards the free end whenthe shaft is rotating counter clockwise (CCW). The thread will move from the free end of the shaft towards the fixed end for clockwise (CW) rotation. See B below.



3. No Lead: Thread remains stationary for both directions of rotation at center and edges of the shaft.
4. Tapered shaft: Thread moves across the surface in the same direction for both directions of shaft rotation. Remounting the shaft end-for-end reverses the direction in which the thread moves across the shaft.
5. Non-level shaft: Thread moves across the surface in the same direction for both directions of shaft rotation. Remounting the shaft end-forend does not reverse the direction in which the thread moves across the shaft.
6. Crowned shaft: Thread moves away from the center for both directions of shaft rotation.
7. Cusped shaft: Thread moves toward the center for both directions of shaft rotation.

Definition of Lead Angle

The lead of a shaft can be compared with other shafts of different diameters by calculating a lead angle. The lead angle is the angle whose tangent is found by dividing the string advance (inches) by the product of the shaft circumference (inches) and the number of revolutions required to advance the string the measured amount.

$$\text{Lead angle} = \frac{\text{Arctan String Advance}}{\text{(Shaft Circumference)(Number of Revolutions)}}$$

Lead specification: It is recommended that the lead angle of the shaft be zero with a tolerance of ± 0.05° (±3’). The information on Shaft Lead Dectection and Interpretation of Results is excerpted from the RMA Handbook: Shaft Finishing Techniques for Radial Lip Type Shaft Seals.

The BSA Educational Services Committee acknowledges the considerable contributions of James Little, Chicago Rawhide North America, in developing this ESC Report.