

TILTING-PAD THRUST BEARINGS

New design cuts power loss

Injecting oil close to the hydrodynamic wedge significantly reduces the amount required by a thrust bearing. This, in turn, means a smaller oil supply system and lower operating costs.

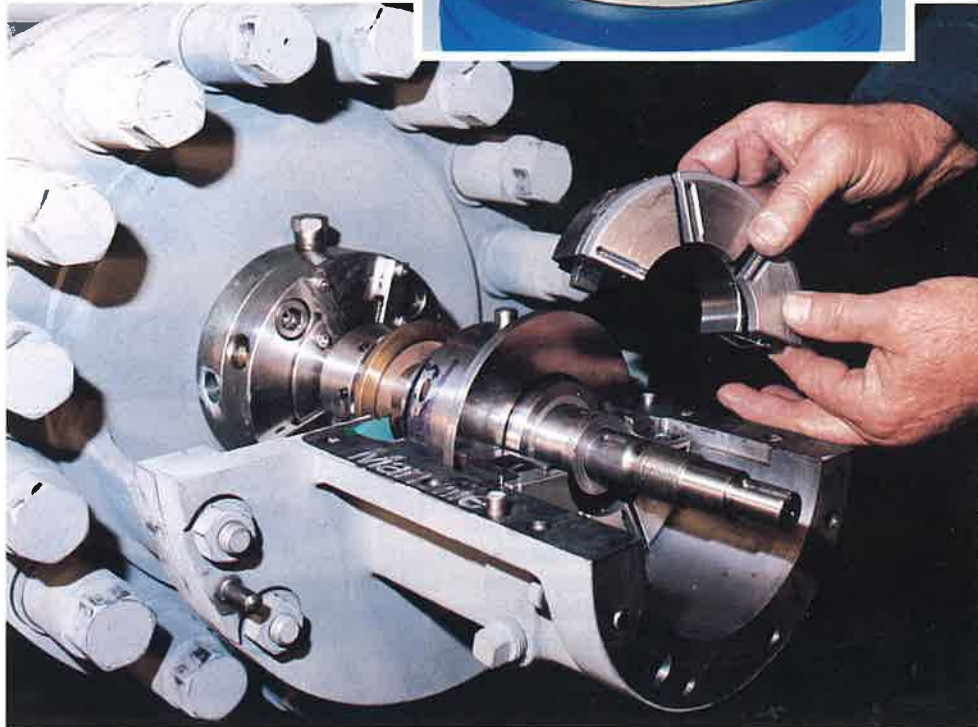


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Tilting-pad, fluid-film thrust bearings have been used for over 75 years, and they are the preferred type where medium to heavy loads must be supported at moderate to high speeds. Typically, the bearings operate with a pressurized (or flooded) lubricant supply. Here, only about 5 to 10% of the oil actually enters the hydrodynamic film wedge; the rest is used to cool the bearing components. Unfortunately, the cooling oil also increases churning or frictional power loss around the rotating collar.

A new type of tilting-pad thrust bearing reduces frictional power loss by using the so-called managed flow concept. In this approach, lubricant is introduced close to the point where the hydrodynamic film wedge forms; thus, most of the oil is used to support the load. This not only reduces the amount of oil required by the bearing, it also reduces that available for churning.

These so-called low-friction-power-loss bearings can operate with oil flow rates significantly lower than those required for equivalent pressurized bearings. Lower oil flow rates provide some additional benefits; namely, smaller oil



supply systems, which reduce capital and operating costs, and the elimination of oil seal rings, which simplifies installation.

However, it should be noted that even with the reduced oil flow, parasitic churning losses can be significant unless the oil is efficiently discharged from the housing. The discharge should be designed so that only a small positive pressure (1 to 2 psi) exists in the bearing cavity.

Leading-edge lubricant feed groove in a tilting-pad thrust bearing (here being installed into a pump housing) introduces oil directly into the hydrodynamic film wedge. As a result, the bearings require significantly less oil to carry a given load and cut frictional power losses.

Operating with an evacuated housing may minimize parasitic churning losses, but it adds the risk of quickly depleting the oil supply should flow be interrupted.

Another potential drawback to low-loss bearings is their higher initial price. However, considering the up-front cost savings (lower losses and less oil to condition), the bearings are cost-effective for most applications.

Available types

Low-loss thrust bearings are of two types. One provides managed oil flow by spray feeding the lubricant; the other employs a leading edge groove (LEG) in each pad or shoe to introduce the oil directly into the film wedge.

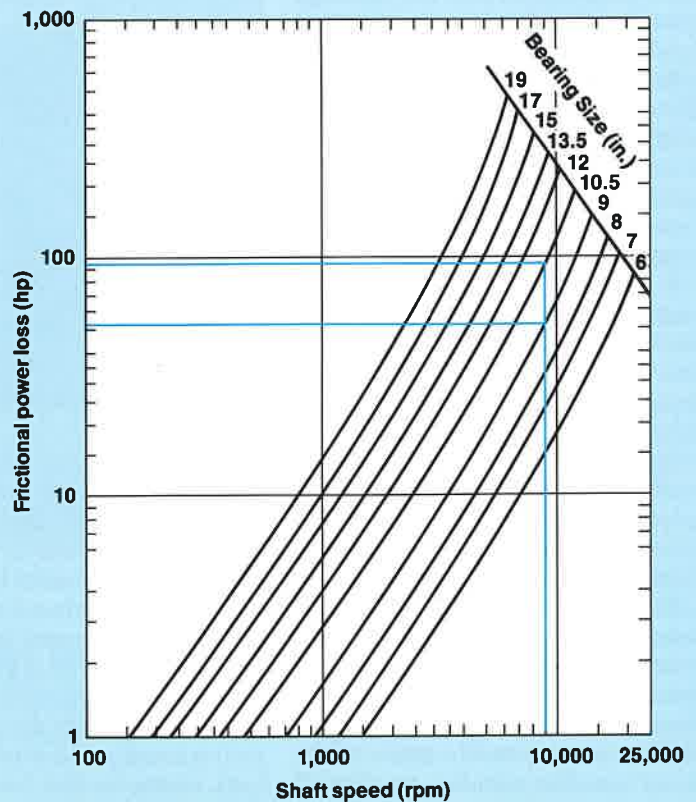
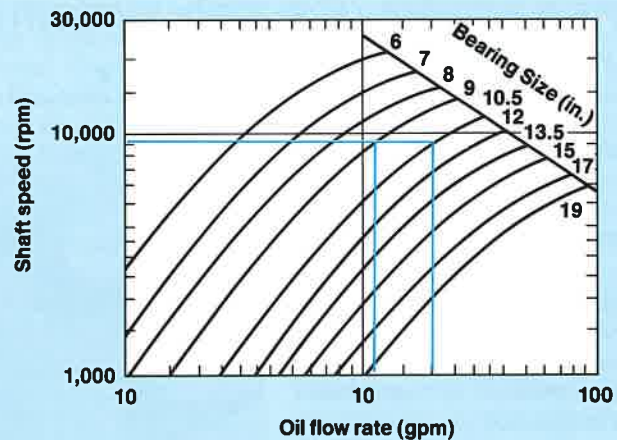
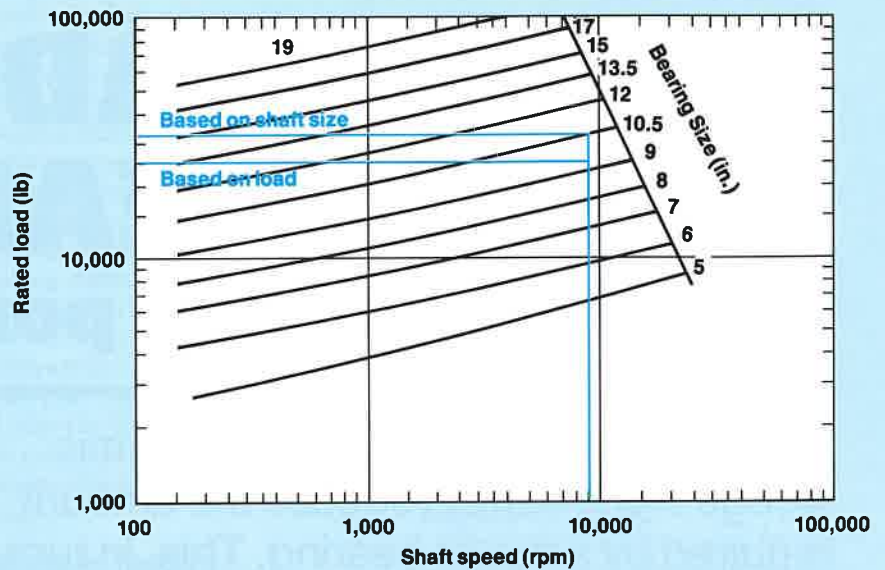
Spray-fed bearings introduce cool oil close to the point of entry into the film wedge. The distribution of the spray jets and the shape of the spray element are controversial topics today. However, it would seem reasonable to conclude that a large number of spray orifices parallel to the shoe leading edge would be more effective than designs with fewer orifices.

Oil is supplied to the spray heads from an external source, and the orifices direct the oil at the rotating collar. Besides reduced oil volume and lower frictional power loss, another potential benefit of spray-fed bearings is that the spray jets could scour off the hot oil carryover that adheres to the rotating collar. Orifice number, size, and orientation, and the gap between them and the collar would influence oil impingement velocity and, therefore, the effectiveness of this approach.

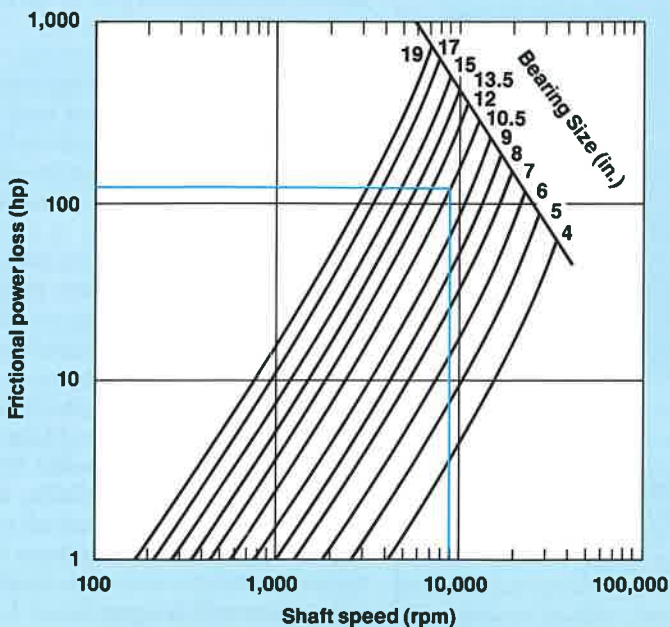
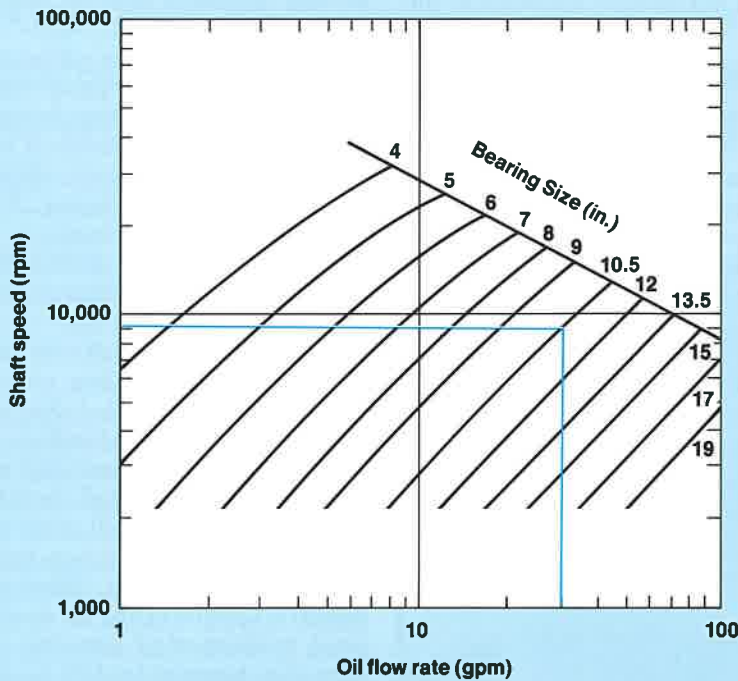
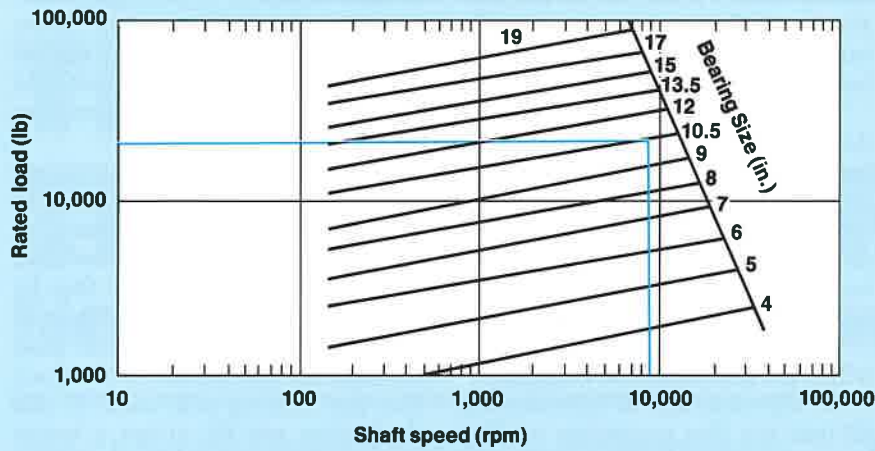
The drawbacks of this design appear to be the impracticality of supplying oil at sufficiently high pressure to effectively scour the hot oil carryover, the recapture of any hot oil carryover disturbed by the jets, the tendency of the small orifices to clog, and the dilution of the cool inlet oil before it is swept into the film wedge. Each of these difficulties could adversely affect bearing load carrying capacity.

The cooler the oil in the hydrodynamic film, the higher its effective viscosity and, therefore, load capacity. Naturally, any dilution of the cool supply oil, or introduction of hot oil carryover in the film,

Leading edge groove bearing



Conventional bearing



GETTING A LEG UP ON THE COMPETITION

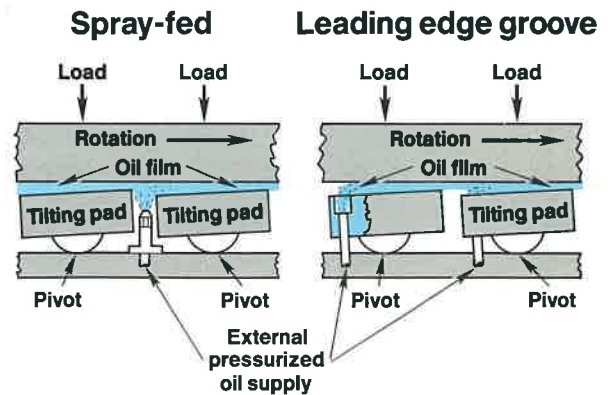
To get an idea of how managed lubricant flow improves bearing efficiency, consider an application in which a bearing must carry a thrust load of 24,000 lb at 9,000 rpm. Lubricating oil is rated at 150 SSU at 100°F and is supplied at 120°F.

First, a tentative selection is made from rated-load curves based on load and speed. In this case, a 10½-in. standard bearing or a 9-in. leading edge groove bearing would carry the required load. However, if shaft size cannot be reduced and a 10½-in. LEG bearing must be used, rated load capacity would be 32,500 lb (vs. 24,000 lb for the standard bearing). The load capacity advantage of the LEG bearing results from its lower operating temperature.

The next step is to compare oil flow rates for the bearings. From the lubricant supply curves, required oil flows are 13.2 gpm for the 9-in. LEG, 23.4 gpm for the 10½-in. LEG, and 36 gpm for the 10½-in. standard bearing. Respective frictional power losses are 52, 94, and 120 hp.

Thus, based on equivalent load ratings, LEG bearings require 63% less oil, which results in 56% lower frictional power loss. Based on equivalent size, LEG bearings require 35% less oil, which results in 22% lower frictional power loss.

Managed lubricant flow can be provided by a spray feeding system or leading edge grooves, both of which introduce oil directly into the hydrodynamic film. In this way, most of the oil is used to carry the load and little is available for churning.



would have a negative impact on bearing capacity. The tendency of the small orifices to clog has the potential to further reduce oil supply flow rate, which could deprive the bearing of the oil necessary to form a full hydrodynamic wedge, creating a situation that can lead to bearing failure.

Leading edge groove (LEG) bearings get their name from the fact that the shoe leading edge is extended to incorporate an oil distribution groove by adding non-effective (nonload carrying) area. A pressurized oil supply connected to the groove introduces cool, undiluted oil directly into the hydrodynamic wedge in a laminar layer that forms between the hot oil carryover and the stationary shoe. The result is an initially cool layer of oil in intimate contact with the shoe babbitt.

This approach has one inherent advantage — it minimizes dilution of the cool supply oil with the hotter oil in the bearing cavity. Oil supply pressure can be varied over a large range (minimum pressure required is 5 to 6 psi), but the bearing never truly becomes a hydrostatic or hybrid type. Again, the improved effi-

ciency of this distribution method allows oil flow rate to be significantly reduced, thereby reducing bearing frictional power losses.

The main drawback of the LEG design is that the bearing can carry loads in only one direction, although it should be noted that the bearing does have limited bidirectional capabilities. The LEG bearing differs from the spray-fed design in two important areas:

- It uses large oil passages, which are not subject to clogging.
- The method of introducing oil into the film minimizes oil film temperature, which in turn increases effective oil viscosity in the film.

Selection factors

The selection process for low-loss thrust bearings is the same as that for conventional flooded configurations. The first step is to identify the operating conditions: load, shaft speed, oil viscosity, and oil supply temperature. The next step is to consult the manufacturer's catalog for dimensional tables and engineering curves.

Rated load curves for a particular bearing are based on a specific lu-

bricant viscosity and supply temperature. Applications that differ significantly from the stated viscosity and supply temperature should be referred to the manufacturer for selection.

If no viscosity or supply temperature restrictions apply, a tentative selection can be made, based on load and speed, from the rated load curve. This selection should then be checked against the dimensional tables to see if the shaft will pass through the bearing ID. If the shaft fits, the bearing will work. If the shaft does not fit, either a larger bearing must be selected, or the bearing originally selected must be overbored.

The manufacturer should be consulted when operating conditions subject the bearing to excessive vibration, high transient load, shock loads, or lubricant deterioration or contamination. Once bearing selection is finalized, the required oil flow rates and resulting power loss can be determined from the manufacturer's curves.

Minimum film thickness is an important bearing safety criterion because a film thickness of at least some "minimum value" will accommodate changes in load and temperature, and deflected or misaligned shafts. It also will allow most foreign matter to pass safely through the oil film. Maximum babbitt temperature is another good indicator of bearing performance because babbitt loses its tensile and compressive strength and is subject to creep at elevated temperatures.

Tilting-pad thrust bearings normally are used in pairs. One bearing element carries the thrust load and is called the loaded or active bearing. The second bearing positions the shaft and carries any transient reverse thrust loads.

Individual bearing elements are generally identified by the number of pads or shoes they contain. Therefore, a double thrust bearing configuration in which each element contains six shoes on each side of the rotating collar would be designated as a 6 × 6 double thrust bearing. In general, fluid-film bearings have an almost infinite life expectancy because they have little or no metal-to-metal contact to cause wear and fatigue. ■

