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Performance Characteristics of Two Tilting Pad Thrust Bearing Designs

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A tilting pad thrust bearing incorporating several changes, as compared to a current standard design, has been developed to provide greater load capacity. Design changes were made to the pad face geometry, the pad support design, and the load equalizing mechanism. Details of the new design features and the bases for their selection are described. Laboratory tests were run to establish operating characteristics to compare to those of a current standard design. Typical test data and comparisons are presented.

1. INTRODUCTION

Tilting pad thrust bearings are widely used in a broad range of rotating machinery because of their relatively high load capacity, reliability, long life, and ability to operate over a wide range of operating conditions. As with the machinery in which these bearings are used, improved operation is always sought, primarily in terms of increased load capacity but also in reduced power loss associated with the bearing. Publications in the past ten years or so have presented results of some of the work in this area by several manufacturers. References [1] through [4] are representative.

The test work reported here provides comparative data from a new design tilting pad thrust bearing (termed HyFilm in the marketplace) and from the conventional "catalog" type thrust bearing manufactured by the company with which the author is associated. The impetus for the development of the new bearing was twofold; 1) increased load capacity, as noted above, and 2) improved operation of the load equalizing mechanism. Although improved equalization can translate directly to increased load capacity in a particular application, the two items were treated independently in the tests and are similarly treated in this report. This is necessary since the rig used for the running tests was not set up to intentionally introduce misalignments to force action of the leveling mechanism. Tests of the leveling systems were made in a static rig.

2. BEARING DESIGN FEATURES

The design features of the catalog bearing are well known because of its wide use for many years. A brief summary of these features is in order, however, since the differences in performance between the two bearings are attributed to the differences in design.

The catalog bearing has six pads, each subtending an angle of 51 degrees, an OD (outer diameter) to ID (inner diameter) ratio of 2.0, and each pad is supported on a hardened spherical pivot resting on the flat surface of the upper leveling link. The thrust pad is thus free to align in any direction due to the "sphere on flat" pivot. The ratio of pad circumferential length (at the mean diameter) to pad radial length is 4 to 3. A photograph of this type bearing is shown in Figure 1. A developed view drawing of this type bearing to illustrate the equalizing mechanism is shown in Figure 2.

The HyFilm bearing differs from the catalog bearing in a number of ways; but for the same basic size and OD to ID ratio, it has the same thrust area and physically occupies the same space, and is thus interchangeable with the catalog bearing. The ratio of pad circumferential length (at the mean diameter) to the pad radial length is 1.0. For an OD to ID ratio of 2.0 and 15%

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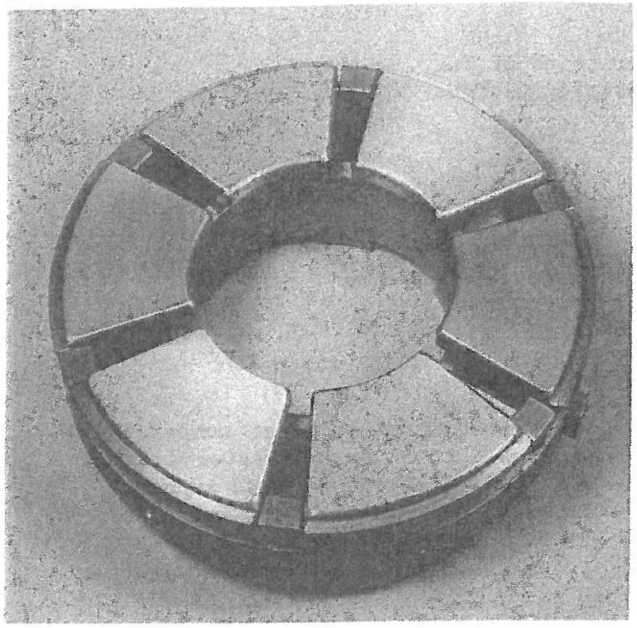

Fig. 1 Catalog type tilting pad thrust bearing

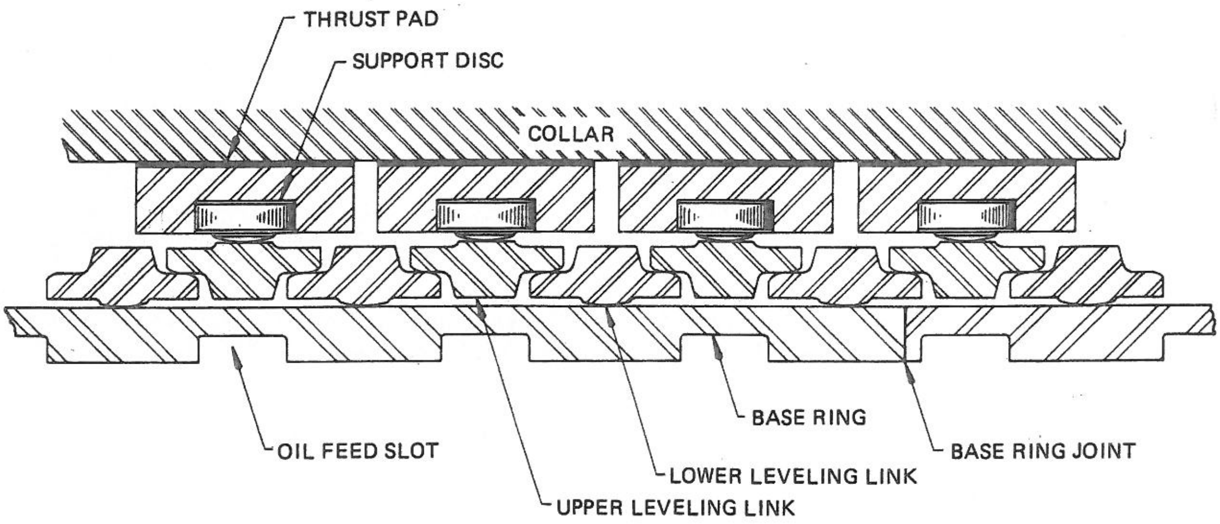

Fig. 2 Developed view of catalog type bearing

groove area, an eight pad bearing results. In order to better control pad deflections in the radial direction, an essentially full length radial rib pivot was chosen. The disadvantage of this type of pivot is that it normally eliminates self-alignment of the pad in the radial direction. This problem was overcome in the HyFilm bearing by supporting the pad on a leveling disc with a spherical surface on its opposite face. This construction is shown in Figure 3. The thrust pad is free to pivot on the radial rib support to generate the hydro-dynamic oil film, and the combination of thrust pad and leveling disc is free to pivot radially to provide alignment. Thus, the advantage of the rib (line) support in better controlling pad deflections is obtained, but the advantage of the point support in allowing alignment radially is retained. This construction is the subject of U. S. Patent No. 4,403,873 and foreign patent applications.

The other basic change in the HyFilm bearing as compared to the catalog style is in the load equalizing mechanism. This is illustrated in Figure 4, showing a developed view similar to Figure 2. The basic difference is that the pivot point of the lower link (or lever) has been located in line with projections of the surfaces on the lower link which contact the spherical lower surface of the leveling disc (or upper link).

In the conventional equalizing mechanism (Fig. 2) the pivot point of the lower link is displaced from the extension of the surfaces which contact the upper link. Thus, the friction force along this plane (which necessarily develops when equalizing action occurs) creates a moment about the pivot of the lower link which must be balanced. One way for this equilibrium of the system to be

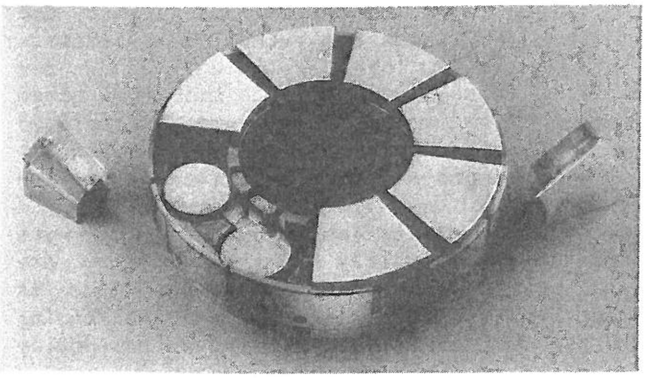

Fig. 3 HyFilm type tilting pad thrust bearing

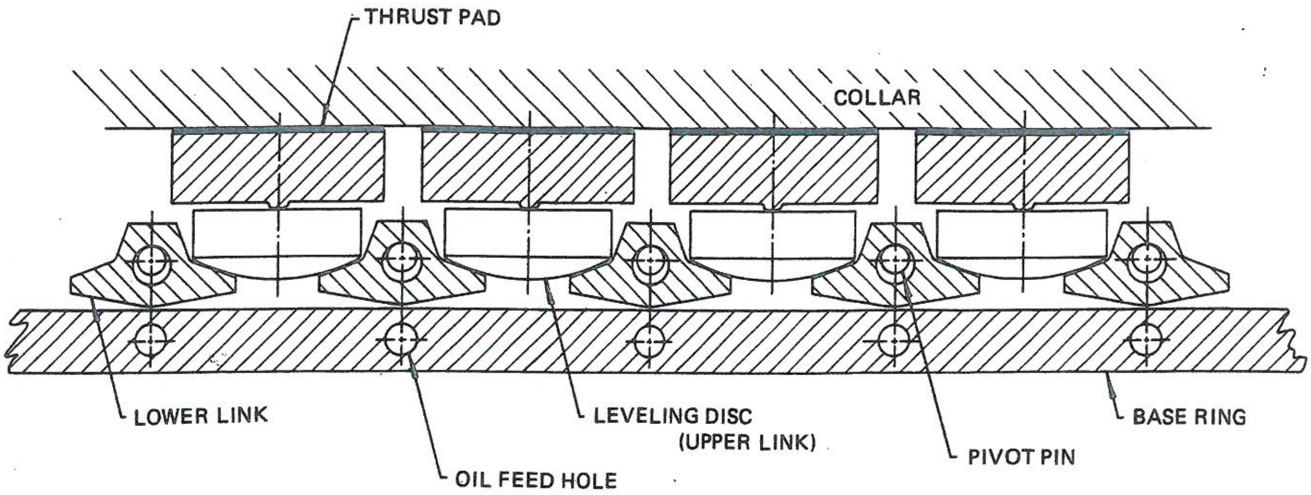

Fig. 4 Developed view of HyFilm type bearing

achieved is by unequal pad loadings. Thus, friction at the contacts of the links can result in unequal pad loadings with this conventional system.

This problem is reduced in the HyFilm bearing by the geometry of the leveling mechanism as described above and shown in Figure 4.

The design of the HyFilm bearing was such, then, that improvements in both load capacity and load equalization were anticipated. The tests reported here were made to confirm those expectations.

3. TEST SETUP & PROCEDURES

The load equalization tests were performed in the rig shown in Figure 5. Here, a static load was applied to the thrust bearing through a thrust plate (collar) loaded by the center hydraulic cylinder. A side load was then applied by the hydraulic cylinder offset from the bearing center. This load was measured, as was the vertical displacement of two thrust pads 180 degrees apart. The side force required for a given pad displacement (action of the equalizing mechanism) is thus an indication of the efficiency of that system. Both types of leveling systems were tested in this rig. The hydraulic pressure in the side cylinder was sensed by a transducer and connected to the X axis of an X-Y recorder. The pad vertical displacements were sensed by proximity probes whose outputs activated the Y axis. Plots were generated at various center loads with one of the equalizing systems and then repeated with the other system, adding the second plot to the corresponding first plot for a direct comparison.

The operating tests were made on 381 mm (15 inch) OD bearings, in both the HyFilm and catalog designs described previously, in the rig shown in Figure 6. This is driven by variable speed DC motors (two 375 KW motors

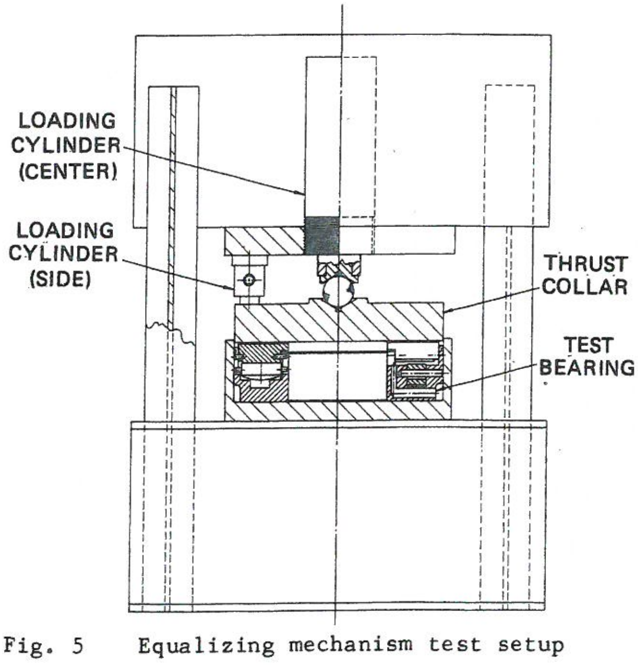

Fig. 5 Equalizing mechanism test setup

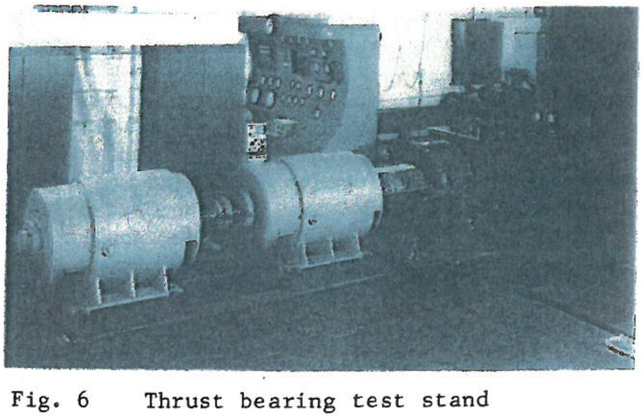

Fig. 6 Thrust bearing test stand

connected in tandem) through a speed increasing gear. One thrust bearing housing is a sliding fit inside the supporting structure and this is loaded by an annular array of hydraulic cylinders. This load is transferred to the other thrust bearing through the shaft with integral thrust collars. The magnitude of the load was determined by measuring the pressure to the loading cylinders.

The oil used in all the tests reported here was a light turbine oil corresponding to ISO VG32. An inlet temperature of 49C (120F) was also a constant. Oil flow rates to the test bearings were constant for a given RPM, regardless of the load on the bearing. These values were:

RPM	Liter/Min.	U.S. Gallons/Min.
2000	41.6	11.0
3000	79.5	21.0
4000	121	32.0
5000	167	44.0
6000	220	58.0
7000	265	70.0
8000	341	90.0

The oil flow rate was measured by turbine type flowmeters. The flow was controlled on the supply side with the discharge being an "open" tangential port at the top of the thrust bearing housing which in turn discharged into a large space around the housing, open to bottom drains.

All data reported here was obtained from one end of the test rig as it was determined that differences in rig construction resulted in differences in performance when a bearing was tested in one end as compared to the other.

Thus, the comparisons made between the HyFilm and the catalog bearings are believed to be due to the differences in the bearings themselves and not to any external factors, as these were held constant.

4. TEST RESULTS

Representative test results are given here as space does not allow extensive presentations, nor is this deemed necessary in order to provide a comparison of the two bearing types.

Figure 7 is a plot obtained from the tests on the two equalizing mechanisms. The significant reduction in force required to produce a given angular movement of the thrust collar using the new mechanism as compared to the conventional is apparent. This translates into more equal thrust pad loadings for any given misalignment when using the new system as compared to the conventional. Similar plots were obtained at loadings from 0.69 MPa (100 psi) to 3.45 MPa (500 psi).

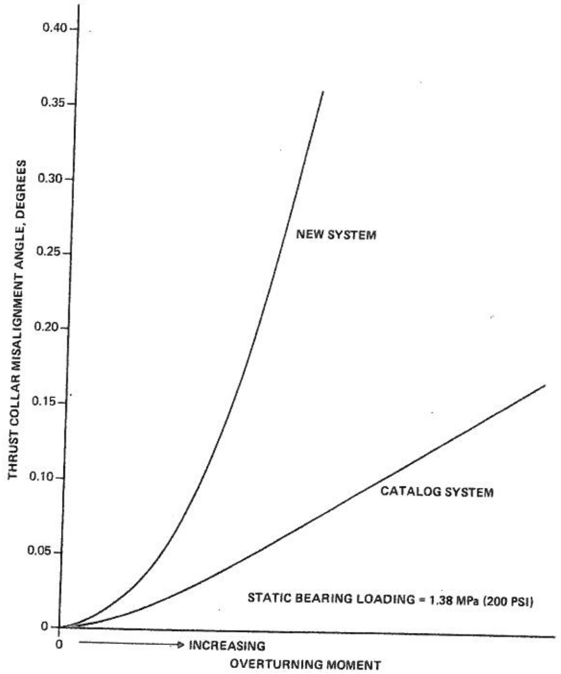

Fig. 7 Plot from test of equalizing mechanisms

The HyFilm bearing was tested in four configurations; center and offset (0.6) pivots in both steel and high strength copper backed pads. The data given here is grouped by pad backing material. In all plots the center pivot catalog type bearing data is given for comparison to the center pivot HyFilm and also to the offset pivot HyFilm.

All thrust pads tested were faced with 1.5 mm of tin based babbitt (ASTM-B23-Grade 2) and were finished by lapping flat. Copper-constantan thermocouples were embedded in the babbitt facings of the pads at various locations, but primarily in the outer trailing edge quadrants. In all tests each pad of the bearing had a thermocouple located in the center of this quadrant, commonly identified as the 75-75 position. All of the pad temperature data given here is from this location, being the average of the six (catalog bearing) or eight (HyFilm bearing) temperature values obtained.

Figures 8 and 9 give temperature data for steel backed pads over a range of loadings at two different speeds. Figures 10 and 11 are similar but for copper backed pads at two different speeds. Figures 12 and 13 look at some of the data with speed as the variable rather than loading.

5. DISCUSSION

Although the 75-75 location may not represent the hot spot on the pad face for all conditions, it is a location commonly used both in reporting test work and in field

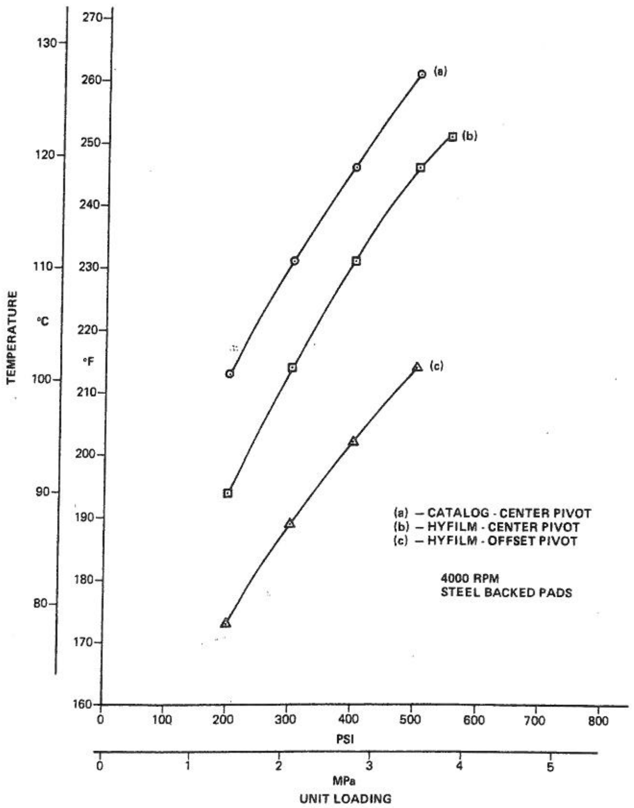

Fig. 8 Bearing temperature versus loading - steel backed pads - 4000 RPM

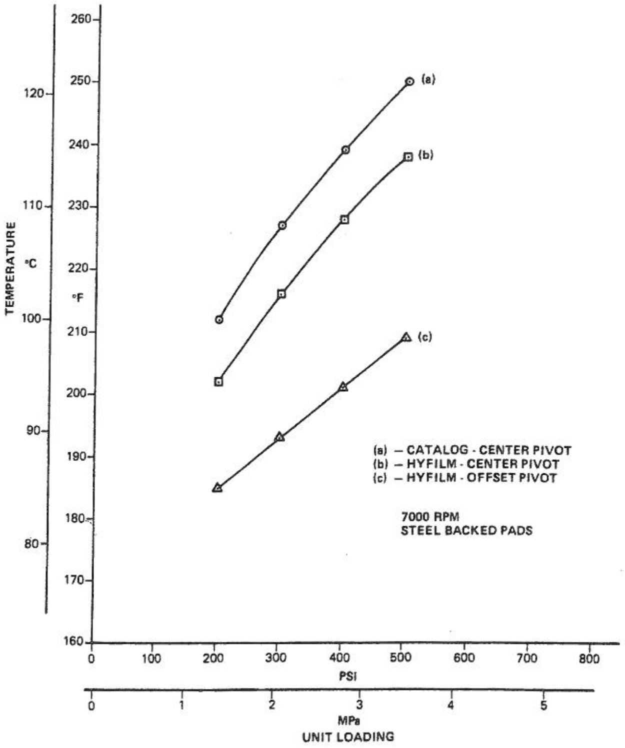

Fig. 9 Bearing temperature versus loading - steel backed pads - 7000 RPM

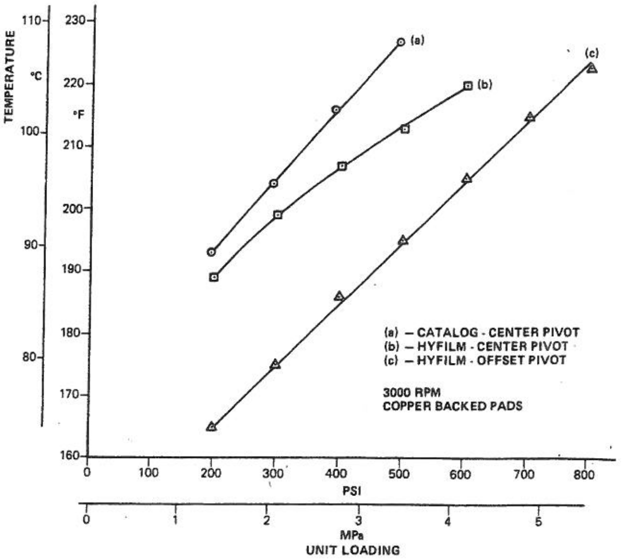

Fig. 10 Bearing temperature versus loading - copper backed pads - 3000 RPM

use. Thus, it not only provides a common location for the comparisons here but also gives data more readily compared with that from actual field applications and other tests.

Figures 8 through 13 indicate the temperature advantage of the HyFilm center pivot bearings as compared to the catalog center pivot bearing. Although it is not possible to give a fixed value in terms of load capacity gain, as this is dependent on speed, load level, and pad material, it can be seen from Figures 8 and 9 that for the steel pads, a gain of about 0.7 MPa (100 psi)

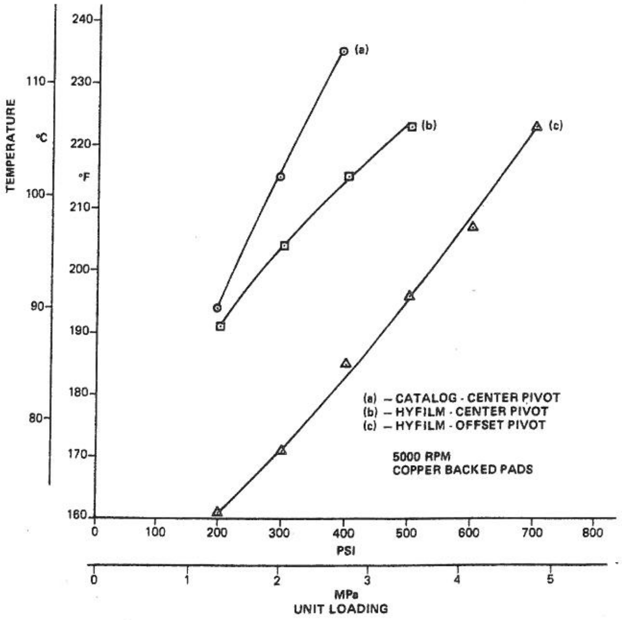

Fig. 11 Bearing temperature versus loading - copper backed pads - 5000 RPM

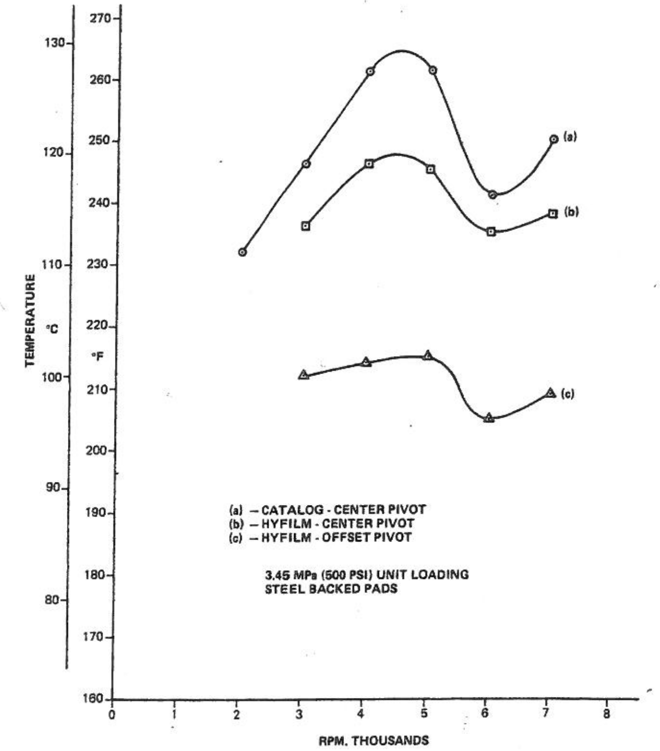

Fig. 12 Bearing temperature versus RPM - steel backed pads - 3.45 MPa (500 psi) loading

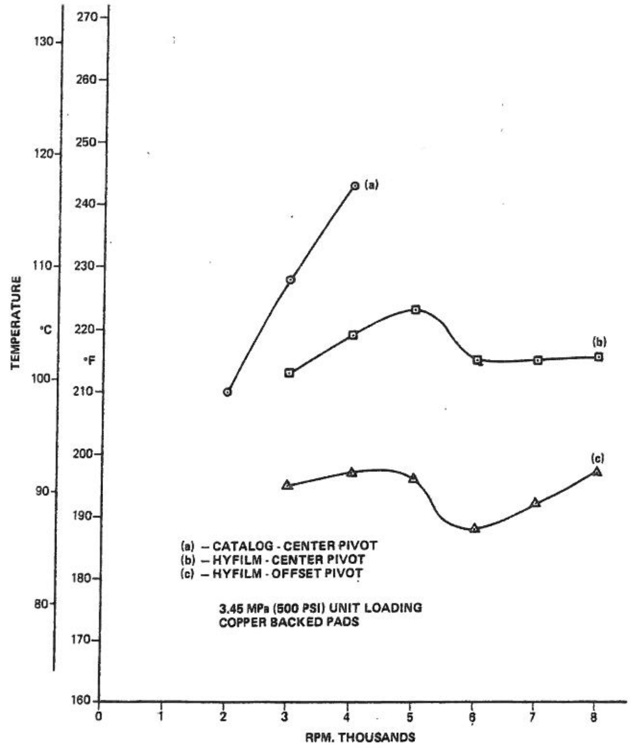

Fig. 13 Bearing temperature versus RPM - copper backed pads - 3.45 MPa (500 psi) loading

is obtained for the conditions given (using a fixed temperature as load capacity criteria).

Figures 10 and 11, for the copper backed pads, indicate an increasing advantage for the HyFilm bearing as the unit loading increases.

Data from offset pivot HyFilm bearings are included in Figures 8 through 13, and the significant temperature advantage of using offset pivots, as compared to center pivots, is clear.

Bearing power loss was not specifically studied in these tests other than to determine values through the use of the oil flow rate and the oil temperature increase (oil out - oil in). Comparisons of this data show basically no difference in loss between the HyFilm and the catalog bearings operating at the same conditions. Although the HyFilm bearing may be operating with a heavier oil film (which would be expected to reduce losses), it also operates at a lower average temperature and thus a higher average viscosity, which would increase losses. These factors appear to somewhat offset each other and this results in little change in power loss, even though there may be significant changes in bearing pad temperature.

However, if the increased load capacity of the HyFilm bearing is used to permit selection of a smaller thrust bearing for a specific application, then the power loss savings can be significant.

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